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SEED POTATOES AND HOW TO PRODUCE THEM

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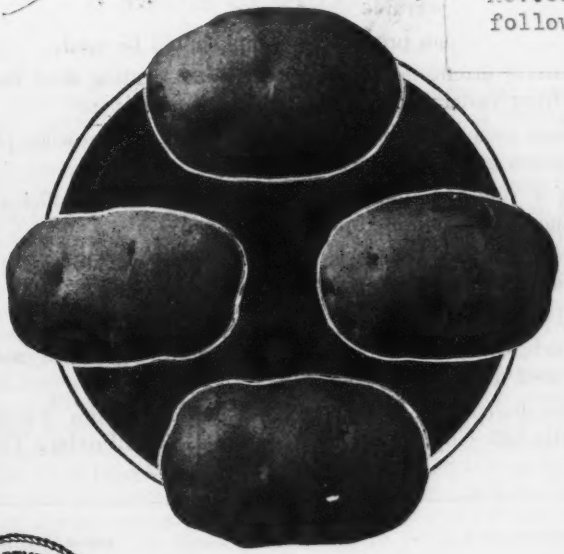

THE AVERAGE PRODUCTION per acre of potatoes in the United States is very much lower than in Canada, Great Britain, and European countries outside of Italy.

One of the reasons for the lower production in the United States is that less attention has been given to the character of the seed. Good seed is one of the determining factors in the production of maximum crops of potatoes.

The use of high-grade seed would increase the returns from the potato crop of the country by many millions of dollars.

The quality of the seed may be improved through the removal of all diseased, weak, or off-type plants as soon as they are observable.

Only seed from productive plants should be used.

Careful attention should be given to securing seed that is free from varietal mixture and that is true to type.

Good seed can not be produced unless the growing plants are given good cultural attention.

As a rule the quantity of seed used is not sufficient to produce a maximum crop.

From 15 to 18 bushels of seed should be used per acre instead of 9 to 11, as at the present time.

All seed stock should be disinfected before planting.

Good storage conditions are essential to insure sound, firm seed at planting time.

This bulletin is a revision of and supersedes Farmers' Bulletin 533, Good Seed Potatoes and How to Produce Them.

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SEED POTATOES AND HOW TO PRODUCE THEM.

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YIELDS OF POTATOES.

A STUDY of the statistical data upon potato crop production in the United States for the last 55 years[1] reveals the interesting fact that relatively little gain in production per acre has been made during this period. To partially minimize seasonal variations in yield per acre the 55-year period has been divided into eleven 5-year cycles and the average production of each cycle compared. During the first 5-year cycle, 1868–1872, the average yield per acre was 94.5 bushels, while in the last 5-year period it was 98.7, or a gain of approximately 4.4 per cent. The averages for the eleven 5-year cycles are 94.5, 88.1, 77.9, 76.7, 74.0, 79.9, 82.2, 96.3, 96.5, 96.0, 98.7 bushels per acre, respectively. A study of these data shows that there was a very appreciable and more or less gradual decline in production per acre during the second, third, fourth, and fifth cycles, or from 1875 to 1892, inclusive, and that during the next three cycles there was a decided increase, the fifth cycle showing a slight increase over the first cycle. From this period until 1908 to 1922 the increase has been a very nominal one, unless we choose to regard the 1918 to 1922 performance as indicating a permanent improvement in the per acre production of potatoes. From the data presented it is evident that the slight gain in average yield per acre (4.4 per cent) in the last of the eleven 5-year cycles over that of the first cycle is not sufficient to account for the increased production of potatoes in the United States. The total average bushel production in the United States for the years 1868 to 1872 was 117,745,800, while in the last 5-year period (1918–1922) the average production was 390,173,200 bushels, or an increase over the first period of more than 231 per cent. During

[1] The statistical data upon which these studies are based were obtained for the years 1868 to 1888 from the United States Department of Agriculture Yearbook for 1917, p. 657; for 1889 to 1895 from the 1920 Yearbook, p. 617; for 1896 to 1920 from the 1921 Yearbook, p. 583; and for 1921 to 1922 from the December 23, 1922, issue of the United States Department of Agriculture Weather Crops and Markets publication, p. 565.

this same period the increase in acreage devoted to potato production has been more than 217 per cent. These data show conclusively that increased production in the United States during the last 55 years has been almost entirely due to increased acreage rather than to any material improvement in cultural practices resulting in larger yields per acre.

Table 1 shows and the accompanying diagrams (Figs. 1 to 4) also show in a graphic way the average acre yields, the farm price per bushel, the acreage grown, the total production of potatoes, and also the population of the United States during the eleven 5-year cycles studied. In the construction of these diagrams it has not been feasible to employ the same scale in any two of them, owing to the great difference in the magnitude of the figures treated. A careful study of the first diagram (Fig. 1), in which the acreage yield and farm price per bushel are given, shows that the acreage-production curve, if drawn on the chart, would somewhat resemble the curve of a scimitar blade, in which the extreme ends of the blade represent the maximum yields for each half of the curve.

TABLE 1.—*Averages of acreage, production, and farm values of potatoes in 5-year periods from 1868 to 1922, inclusive.*

5-year period.	Number of acres.	Production (bushels).		Farm value on Dec. 1.	
		Total.	Per acre.	Total.	Per bushel (cents).
1868 to 1872	1,246,200	117,745,800	94.5	$64,123,600	54.5
1873 to 1877	1,529,800	134,773,200	88.1	68,665,600	50.9
1878 to 1882	1,934,200	150,706,200	77.9	85,547,200	53.8
1883 to 1887	2,284,000	175,197,800	76.7	82,295,000	46.9
1888 to 1892	2,633,800	194,939,400	74.0	93,012,600	47.7
1893 to 1897	2,900,400	231,757,800	79.9	95,258,400	41.1
1898 to 1902	2,968,200	243,866,400	82.2	117,671,600	48.3
1903 to 1907	3,213,200	309,568,200	96.3	170,652,800	55.1
1908 to 1912	3,644,400	351,793,800	96.5	213,038,200	60.6
1913 to 1917	3,812,400	366,045,600	96.0	322,292,400	88.0
1918 to 1922	[1] 3,953,200	[1] 390,173,200	98.7	425,826,000	109.1

[1] The data for 1922 are subject to revision.

The gradual decline in yields during the first half of this period is thought to be largely due to the following factors:

The ravages occasioned by the Colorado potato beetle during the early period of its invasion of the eastern United States.

The financial depressions of 1877 and 1893, which brought about a well-marked decline in agriculture in New England, New York, and the other heavy potato-producing areas of the northeastern United States.

A gradual depletion of soil fertility.

Of the factors which have checked the downward tendency and contributed most largely toward a return to the old production level the following are thought to have been most potent:

The influence of the agricultural experiment stations, agricultural colleges, and the United States Department of Agriculture through experimentations, demonstration, and the dissemination of literature.

The influence of the Bordeaux-mixture treatment in the control of fungous diseases affecting the potato.

The development of special potato-growing sections, as, for example, Aroostook County, Me., the Atlantic Coastal Plain trucking region, the Greeley and Carbondale districts of Colorado, and many other areas, in which the average yield is approximately from two to three times the general average for the United States.

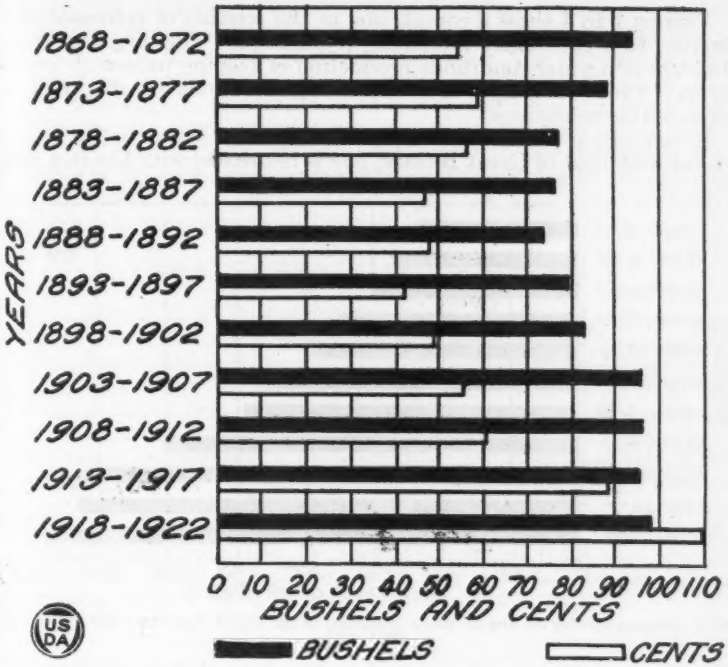

FIG. 1.—Diagram showing the average number of bushels per acre and the average farm price per bushel of potatoes grown in the United States by 5-year periods from 1868 to 1922.

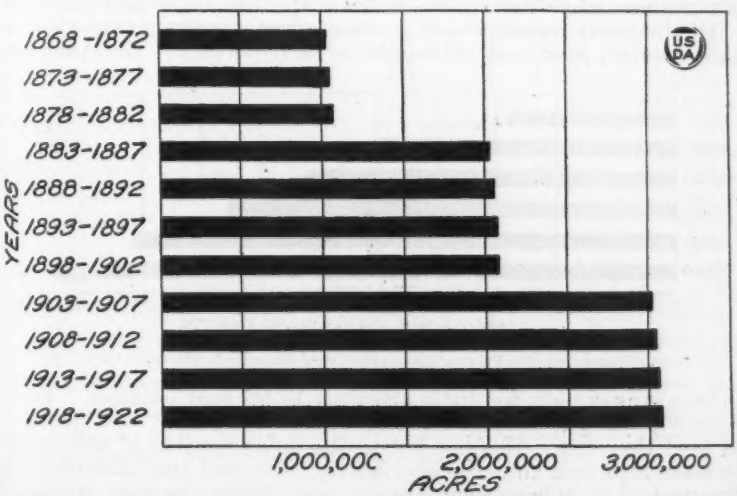

FIG. 2.—Diagram showing the average potato acreage of the United States by 5-year periods from 1868 to 1922.

Figures 1 to 4 show a comparison of the relation of increased production to a constantly increasing population. The diagrams show that under normal conditions production is keeping pace with population. Crop shortages are, therefore, the result of abnormal or unfavorable conditions.

In comparing the average crop production of potatoes in the United States with that of Great Britain, one is impressed with the fact that

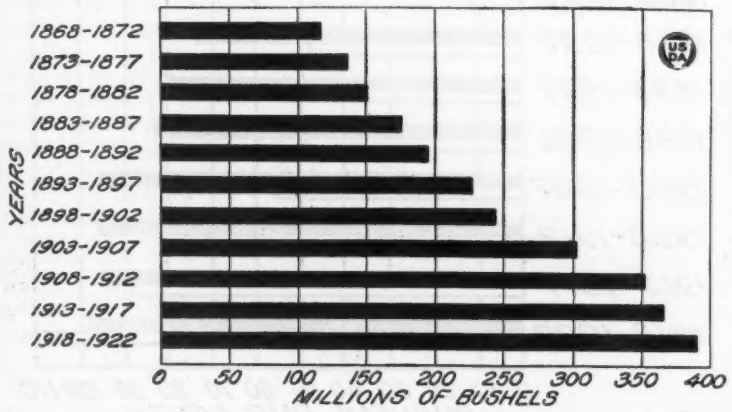

FIG. 3.—Diagram showing the average potato production of the United States by 5-year periods from 1868 to 1922.

generally speaking we have much yet to learn before we can raise our average to that of that country. During the years 1901 to 1910, inclusive, the average acre yield in Great Britain was approximately 200 bushels, while that in the United States was not quite 93 bushels.

Of the many causes which produce a low average potato yield in this country, poor seed is thought to be important. The American

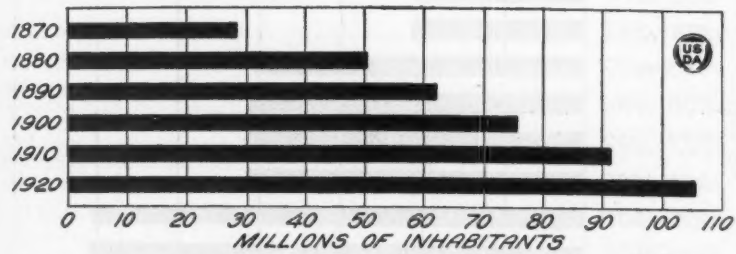

FIG. 4.—Diagram showing the population of the United States by decades from 1870 to 1920.

potato grower pays too little attention to his seed potatoes. European growers pay very strict attention to the quality and quantity of seed they use. This has led to the differentiation of the potato growers into seed and crop specialists. The seed specialist makes a business of producing high-quality seed, while the crop specialist produces a high-grade table potato. Until rather recently no such differentiation, at least to any marked extent, could be claimed in

this country. However, with the adoption of seed-potato inspection and certification in California, Colorado, Idaho, Kentucky, Maine, Maryland, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New York, Oregon, Pennsylvania, South Dakota, Utah, Vermont, Washington, Wisconsin, and all of the Canadian Provinces, groups of seed-potato growers are gradually being evolved. A further stimulus to those who are engaged in the production of seed potatoes is the increasing demand for good seed stock at prices which are sufficiently remunerative to well repay the grower for the extra care given to the crop.

WHAT CONSTITUTES GOOD SEED.

The question of what constitutes good seed is a vital one, and possibly no two persons would fully agree in every particular upon this point. Good seed may be defined as follows: Somewhat immature tubers—reasonably uniform in size and shape, with skin bright and free from scab—firm and sound, with first sprouts just starting. Seed of such quality when given suitable cultural conditions can be relied upon to produce a remunerative crop, other things being favorable. If in any given year it were possible to plant the entire potato acreage of the United States with first-class seed stock the total production would be increased from 10 to 25 per cent. Based on the average production for the 5-year period from 1918 to 1922, this increase would represent from 39 to 97½ million bushels, or an increase in money value of $40,333,000 to $106,333,000.

PURE SEED.

The importance of securing pure seed of a given variety is best appreciated by the southern truck grower, who at the present time is practically dependent on northern-grown seed potatoes for his early crop. In the past, though not to so great an extent at the present time, it has frequently happened that Irish Cobbler seed potatoes have contained 5 or more per cent of varietal mixture. As a rule this mixture consists of a late-maturing variety, generally the Green Mountain, which sets and matures its tubers at a later date than the Irish Cobbler and in consequence is not ready to harvest when the bulk of the crop is fit for marketing. The truck grower aims to harvest his crop as soon as most of the tubers have reached a merchantable size. It requires little imagination to see that the grower is a direct loser in proportion to the percentage of mixture in the seed planted. If his yield is 40 to 75 barrels per acre with a 5 per cent mixture he has sustained a gross loss of 2 to 3¾ barrels per acre, or double this quantity if a 10 per cent mixture occurs. Usually the price of early potatoes ranges from $3 to $5 per barrel, the highest price being obtained for the first lots harvested. Assuming that the crop sells at an average of $4 per barrel, the gross loss on the lowest yield would be $8 and on the highest $15 per acre. It is apparent, therefore, that every care should be exercised in securing seed stock free from varietal mixture.

UNIFORMITY IN SIZE AND SHAPE OF TUBERS.

Under normal conditions of growth many present-day commercial varieties are very variable in size and shape of tuber. To some extent both size and shape are determined by the character of the soil, rate of planting, fertilization, and cultural care given the growing crop. Inheritance, however, plays a very important part. Most varieties contain within themselves distinct varietal strains which when isolated are much more uniform in respect to size and shape than the variety itself. Other things being equal, the variety or varietal strain that produces the greatest number of fair-sized shapely tubers and the smallest number of ill-shaped and small tubers should prove the most valuable, because it involves less waste to both the grower and the consumer. It is particularly important at present that such strains be developed, because there is an increasing demand for fancy table stock to satisfy the requirements of a large and discriminating class of consumers who are insisting on greater uniformity in size and shape and are willing to pay a premium on such grades.

DEVELOPMENT OF HIGH-GRADE SEED POTATOES.

The successful production of high-grade seed potatoes is very largely dependent upon the following factors: (*1*) *Starting with a good strain;* (*2*) *the proper treatment of the seed;* (*3*) *thorough preparation and proper fertilization of the soil;* (*4*) *the following of the best cultural practices, including protection against insect and fungous pests;* (*5*) *the elimination of all mixtures and all diseased or weak plants; and* (*6*) *the careful harvesting and proper storage of the crop.*

SECURING A GOOD STRAIN OF SEED.

If the strain of seed you are using is lacking in vigor, it is generally advisable to discard it and purchase a new lot from some reliable grower whose stock you have reason to believe is superior to yours. This suggestion is made as the result of a rather wide experience in trying to improve poor strains of potatoes through selection methods. Such attempts have usually resulted in failure, and it is felt that as a rule much more satisfactory progress can be made by starting with a new strain. Further improvement can usually be secured through selection.

SEED-POTATO IMPROVEMENT BY SELECTION.

The improvement of seed potatoes by selective processes has long engaged the attention of the potato grower. Recent experimental evidence seems to indicate that the possibilities of improving potato seed stock by selective processes alone are not as great as many writers upon this subject have claimed. To those who have devoted much time and effort to the improvement of the potato by selection it would appear that the chances of finding superior yielding true-to-type strains within a variety are not as great as has been believed. The chief advantages to be derived from seed-potato selection practices are the elimination of diseased and weak plants and the removal of varietal mixtures.

IMPROVEMENT PRACTICES.

Five improvement practices may be used in securing a high-yielding and commercially desirable strain of potatoes: (1) The tuber-unit method, (2) hill selection, (3) mass selection, (4) field roguing, and (5) strain testing.

In early editions of Farmers' Bulletin 533 considerable emphasis was laid upon the tuber-unit method of seed-potato improvement; subsequent experiences of the writer and others have indicated that this method is not as satisfactory or as practical in operation as the other four methods suggested. It is thought desirable, however, to briefly describe the tuber-unit method because some of its processes are applicable to other selection methods.

TUBER-UNIT METHOD.[2]

The tuber-unit method, as now generally understood, consists in selecting from the seed bin before planting time a considerable number of the most perfectly shaped tubers ranging from 6 to 8 ounces in weight. When planted, these tubers are quartered, as dropped, into four as nearly equal parts as possible, by splitting the bud-eye cluster twice from seed to stem end of the tuber. In other words, the tuber is cut through its longitudinal axis. The four pieces of each tuber are dropped consecutively in the row at a distance of from 10 to 12 inches apart in the furrow. All tubers showing discoloration of the flesh or other evidence of disease should be rejected. By allowing an additional spacing between each set of fours, the four plants from each tuber are definitely isolated from adjoining ones and the grower can readily observe any variation in vigor and uniformity between the various units planted. This method also enables him to detect any mixtures that may occur in the variety. All mixtures should at once be removed. By marking the units which appear to be the most uniform in size, vigor, and type when the plants are still in vigorous growth, the first step in selection has been accomplished. At digging time the product of each unit is separately harvested and a further selection made from the marked units of all tubers which most nearly approach the size, shape, and smoothness desired. The selected tubers of each unit should be separately placed in small sacks, preferably cotton or burlap, numbered with both field and unit numbers, and stored to await further examination. The final examination should produce data on the number and weight of merchantable and unmerchantable tubers and their general conformity in size, shape, and smoothness of the type desired. From each of the units retained 10 of the best tubers should be selected for the next season's planting.

It is desirable to maintain the study of each selection on the tuber-unit basis the following season, because it permits a more accurate comparison of the behavior of each. The 10 selected tubers from each original unit will give 40 plants for study the second year. All selections which do not produce a reasonably uniform lot of plants should be marked for rejection. At harvest time the progeny of each selec-

[2] For further information concerning the arrangement of a tuber-unit selection plat and a convenient system of note taking, see Stuart, William, The "tuber-unit" method of seed-potato improvement. U. S. Dept. Agr., Bur. Plant Indus. Cir. 113, pp. 25-31, 2 fig. 1913.

tion should be kept by itself and the same data recorded as those taken on the crop grown from the original tuber unit. Only the product from such 40-hill rows as meet the most rigid requirements should be retained. The further conduct of the work will consist in the multiplication of the selected strains for field planting and the elimination of weak plants.

HILL SELECTION.

The hill-selection method consists in marking the most promising plants during the growing season and at harvesting time saving only those which give the greatest promise. (Figs. 5 and 6.) The progeny of each hill should be kept separate and the same data taken as outlined for the tuber unit. Plant on the tuber-unit or progeny-

FIG. 5.—Progeny of a mosaic-infected potato plant of the Triumph variety on the left (*A*) and of a healthy plant on the right (*B*). Bin selection of such seed would result in taking at least two tubers from the mosaic plant. If small tubers were used all would come from diseased plants. In hill-selection work the progeny of plant B should be saved.

row basis the following season. For the sake of uniformity a definite number of tubers (five or more) should be planted from each hill selection. From this point on, follow the methods given in tuber-unit work.

MASS SELECTION.

Mass selection differs from hill selection in only one respect, which is that the tubers from the individually selected plants are not kept separate. Generally those who practice mass selection do not go to the trouble of marking promising individual plants during the growing season, but simply go through the field before harvesting the whole crop and dig by hand as many plants as may be desired to secure the necessary quantity of seed that show the desired vigor and stem characters thought to be correlated with productiveness, trueness to type, and uniformity in size of tubers of the particular variety grown.

FIELD ROGUING.

Improvement of the seed stock through field roguing consists in the removal of all diseased, weak, off-type, or varietal-mixture plants during the growing season. The successful removal of such plants does not necessarily involve an intimate knowledge of the various diseases affecting the potato, but it does require that the person doing the roguing be able to tell whether a plant is normal or abnormal in appearance. A sufficient field area should be rogued the first year to provide the quantity of seed necessary to plant the full acreage to be grown the ensuing season. The area to be rogued should be gone over at least three times during the growing season, to insure the removal of all plants affected with transferable diseases, such as mosaic and leaf-roll, as soon as their presence can be detected. In the field-roguing method no attempt is made to select the progeny of individual plants at harvesting time, the whole crop being dug and all desirable seed stock gathered and stored in bulk.

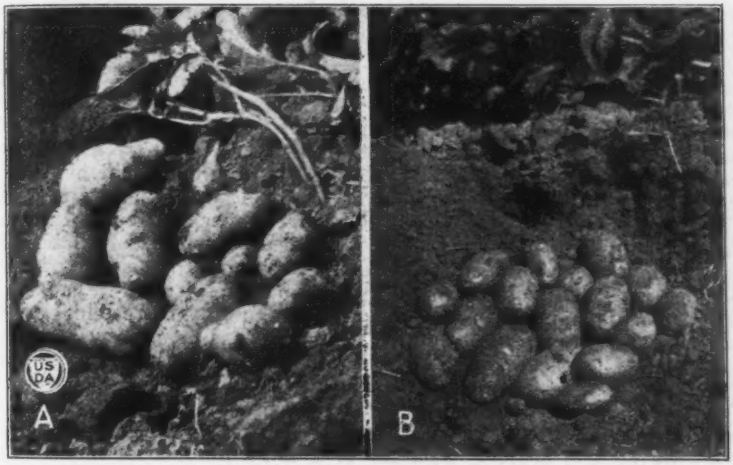

FIG. 6.—Progeny from abnormal (*A*) and normal (*B*) plants of the Russet Burbank potato. Plant A is known in the West as a degenerate or run-out plant, and the disease with which it is affected is probably identical with that recently termed "spindle tuber." It is a communicable disease and may become serious. In hill-selection work the progeny of plants such as *B* should be saved.

STRAIN TESTING.

The improvement of seed potatoes by the strain test, or, as it might more properly be termed, the "source-of-seed test" method, consists in securing as many as possible desirable lots of seed stock of the same variety from different growers throughout a given district or State, or even from various States, and carefully studying their behavior when grown side by side under identical soil and cultural conditions. Experimental studies by this method of seed improvement have demonstrated that some lots or strains of seed stock are far superior to others; in fact, differences in yield of more than 100 bushels per acre have been noted between the lowest and highest yielding strains. Furthermore, it has been conclusively demonstrated by numerous trials that these yields were not accidental, but that in practically every instance the high-yielding strains have consistently given larger yields wherever tested.

The improvement of seed stock by this method does not consist in the actual isolation and development of a strain from a given variety, but rather in locating, as it were, by comparative tests the really superior sources of seed stock. The actual improvement accomplished is measured by the success attending one's efforts in getting live, up-to-date growers to discard their inferior strains and purchase the superior one, as shown by the tests made.

The practical operation of such a movement may be best emphasized by stating that in 1921 over 100 potato growers in Wisconsin grew seed stock of a superior strain of Triumph potatoes located in this manner in 1918.

It should be remembered that whatever selection practice is pursued the fields devoted to the production of high-quality seed must be carefully rogued if the vigor of the seed stock is to be maintained.

RELATIVE MERITS OF THE PRECEDING PRACTICES.

In the preliminary discussion of seed-potato improvement in this bulletin it is intimated that the chance of securing a superior strain of a commercial variety of potato through selective processes is not as great as earlier writers on this subject have claimed. A careful consideration of all the experimental evidence thus far presented would seem to justify the conclusion that the tuber-unit method of seed-potato improvement does not afford as satisfactory a starting point for selection work as the hill-selection method. The evidence at hand would also seem to indicate that neither of these practices is to be commended to the average grower of seed potatoes, as both methods involve an expenditure of a greater amount of time and effort in properly observing the details necessary to their successful application than can reasonably be expected of such a grower. The tuber-unit and hill-selection methods can only be recommended to those growers who have ample time or means to undertake these studies and to those experiment-station investigators who have the facilities necessary for carrying on such work.

The "mass-selection" and the "field-roguing" methods are more nearly adapted to the average grower, as neither method involves the growing and keeping separate of a large number of individual selections. Both are so simple of execution that any person of ordinary intelligence can practice them.

Strain testing involves a somewhat more elaborate plan of operation, in that it requires the purchasing and growing of several strains of a given variety under as nearly identical conditions as it is possible to supply. This method of seed-potato improvement may be best undertaken by the type of men suggested for the conduct of the tuber-unit and hill-selection systems. The average grower should avail himself of the findings of those engaging in strain testing and purchase his seed from those growers having the most desirable seed stock, as demonstrated by such tests.

REQUIREMENTS FOR SUCCESS.

The only requirements for the successful practice of the first two methods of seed selection are a reasonable degree of painstaking effort on the part of the grower, some 12-inch garden labels, a small pair of balances, a sufficient number of suitable small sacks, and a

safe place in which to store the selected tubers until required for the next season's planting. In addition to this, the grower should have a breeding plat in which each season's selections can be developed up to the point of field-planting stock. This selection or seed plat should be located at as great a distance from the commercial potato field as possible in order to secure the greatest degree of isolation that is feasible. Heretofore the problem of isolation has not received due consideration. This was largely owing to the fact that the seriousness of such diseases as mosaic, leaf-roll, curly-dwarf, streak, and spindle tuber has only recently come to be recognized. The fact that all of these diseases are readily transmitted from diseased to healthy plants through the instrumentality of plant lice, or aphids, and the further fact that as yet there is no reliable information as to the distance insects may transport these diseases suggest as complete isolation of the seed plat as possible. The ultimate success of the seed plat in so far as the elimination of tuber-borne diseases is concerned rests largely upon the ability of the grower to recognize diseased plants and the promptness with which they are removed from the seed plat and destroyed. Frequent and thorough inspections of the seed plat are necessary to insure the largest possible reduction of diseased plants and to reduce the transmission of disease from diseased to healthy plants.

SEED TREATMENT.

It is impossible to produce high-grade seed potatoes if the seed planted is infected with disease organisms capable of infecting the crop. The disinfection of the seed potatoes is therefore necessary if the best results are to follow. The two diseases for which seed potatoes are ordinarily treated are common scab and black scurf, or Rhizoctonia. The two disinfecting agents recommended for such treatment are formalin and corrosive sublimate (mercuric chlorid, or bichlorid of mercury). Formalin is as effective against the common scab as corrosive sublimate, but it does not give as good results in the destruction of the black-scurf fungus. When the latter is present on the tubers corrosive sublimate should be used. The formulas recommended for these two disinfectants are as follows:

(1) Formalin, 1 pint.
Water, 30 gallons.

(2) Corrosive sublimate, 4 ounces.
Water, 30 gallons.

If the formalin treatment is selected the seed potatoes should be soaked in this solution from one-half to 1½ hours. Recent experiments by Dr. I. E. Melhus, of the Iowa Experiment Station, indicate that an immersion of the seed potatoes for 2 minutes in a formalin solution of twice the strength mentioned heated to a temperature of 122° F. and covered for an hour after their removal from the hot liquid is just as effective as the longer treatment in the cold solution.

When the corrosive-sublimate solution is used, the length of the immersion should be governed by the condition of the tubers and their freedom from, or the severity of, the black-scurf infection. If the tubers are dormant and they are more or less infected with the sclerotia of the black scurf the treatment may be prolonged to 1½ or 2 hours. If they have started to germinate and are reasonably free from black scurf the period may be shortened to a half hour or less.

The treated tubers should on no account be allowed to come in contact with such receptacles as old sacks and barrels in which diseased seed has been handled, as they are almost certain sources of reinfection.

PREPARATION AND FERTILIZATION OF THE SOIL.

Strong, vigorous plants can not be produced on land that has been poorly prepared or that is deficient in available plant food. Seed potatoes should be grown on land that has been deeply plowed and thoroughly prepared to receive the seed. It should be well supplied with organic matter and available plant food. A clover or alfalfa sod furnishes the organic matter and considerable of the plant food. Barnyard manures or commercial fertilizers, or both, will supply the additional plant food necessary to produce a good crop.

CAREFUL CULTURAL PRACTICES.

The vigor of the seed stock produced is to a large extent dependent on the care given to the growing crop. Uniformity in the size of the tubers is to a large extent governed by the rate of planting. Closer planting should be practiced in the growing of seed than of table stock. Some growers in Aroostook County, Me., space their rows from 32 to 36 inches apart and the plants in the row 8 to 12 inches. The crop should be cultivated as frequently as may be necessary to provide the most suitable growing conditions.

Every effort should be made to protect the plants from injury by insect or fungous pests. Leaf-eating insects can be effectively controlled if the plants are thoroughly sprayed with arsenical poisons; sucking insects with contact solutions, such as kerosene emulsion and nicotine; and fungous diseases, such as the early and late blights, with Bordeaux mixture. In every operation it should be remembered that whatever contributes to the health of the plant increases the vigor of the seed stock produced.

ELIMINATION OF VARIETAL MIXTURES AND DISEASED OR WEAK PLANTS.

The vegetable-seed growers employ the term "roguing" to denote the process of removing all mixtures or off-type plants from the seed plat. As this term, when understood, is a brief and yet sufficiently descriptive way of indicating the process of eliminating all undesirable plants or "rogues," it is proposed to use it in this connection.

It is an easy matter to rogue a seed-improvement or selection plat during the growing season. Varietal mixtures are more easily detected when the plants are in bloom. Weak plants are usually apparent in the early stages of their growth, as are also certain types of diseases, such as mosaic and black-leg, although both may appear later. Plants infected with Rhizoctonia and Fusarium are usually not apparent until the latter part of the growing season. It is evident from these statements that in order to rogue the seed plat thoroughly it is necessary to make two or three examinations of the field or plat during the growing season. Further roguing should be done when the crop is harvested by discarding the progeny of all low-producing plants. (Fig. 5, *A*.)

MONETARY VALUE OF GOOD SEED POTATOES.

The producer of high-grade seed potatoes is justly entitled to a fair monetary return for the special efforts he has made to produce quality seed stock. This is especially true where a seed plat is maintained year after year and the crop has been officially inspected and passed by a duly authorized seed-certification inspection officer. Just what increase in price over ordinary stock one is entitled to receive for such efforts and for the inspection fees involved is not an easy matter to determine. It is believed that a premium of 50 cents per bushel over the market price of table stock of the same variety is ordinarily sufficient to amply repay the grower. Opinions, however, will differ upon this point. At the present time the price of certified seed stock varies all the way from $1 to $3.50 per hundredweight—60 cents to $2.10 per bushel.

IMPORTANCE OF TUBER SHAPE.

Reasonable trueness of the tubers to varietal type is generally demanded by the purchaser of certified seed. And most writers who have dealt with the subject of good seed have always placed strong emphasis upon the importance of its being true to type. Rather recently, however, some scientific as well as practical growers have been disposed to regard tuber shape as being of less importance than has been previously supposed. They have come to regard tubers that have departed from the type as a result of unfavorable environmental conditions as being satisfactory for seed purposes.

As a result of a long-continued preachment of the undesirability of slightly off-type tubers for seed purposes many cars of otherwise high-grade seed stock have been annually rejected by the southern truck grower. This is particularly true in the case of conspicuously flattened and somewhat elongated tubers of the Irish Cobbler variety. The Irish Cobbler grower in the South has come to demand roundish tubers and is suspicious of the purity of seed stock containing flattened and somewhat elongated tubers and generally protests their acceptance as strictly first-class seed stock. In fact, he is inclined to regard the off-type tubers as Green Mountain. The only obvious way of correcting these firmly rooted convictions is to demonstrate experimentally that off-type tubers resulting from unfavorable soil, cultural, or climatic conditions are no more likely to produce off-type progeny than are normal-shaped ones. This statement, however, does not apply to off-type tubers resulting from disease; such tubers should not be planted. The spindle tuber recently recognized by pathologists as a communicable disease is very similar in its method of transmission to that of leaf-roll and the mosaic disease. Figure 6, *A*, represents a fairly good example of spindle tubers. It is important, therefore, in the purchase of somewhat off-type seed potatoes to know whether the change in shape is really due to unfavorable environmental factors and not to disease.

XUM

CAREFUL HARVESTING AND STORAGE OF THE CROP.

The average grower does not fully appreciate the importance of using every means to prevent the mechanical injury of the tubers during the process of harvesting and storing. If the crop is grown on land containing a plenteous admixture of small stones the tubers are almost certain to be more severely injured in harvesting than when grown in a sandy loam soil. Hand digging is not always feasible, but it is believed that where small stones abound in the soil it will be desirable to harvest the home seed plat by hand. Much injury will be avoided if the seed stock designed for planting the field plat of the ensuing year is picked directly into crates in which it is allowed to remain throughout the storage period.

The storage conditions necessary to insure vigorous seed at planting time are more easily provided in the North than in the South. In the former region a well-constructed cellar, pit, or cave serves reasonably well. The main thing is to keep the room temperature sufficiently low to retard germination. The ideal seed tuber is one which has not wasted any of its stored-up energy by excessive loss through sprouting. (Fig. 7.) It should be firm, with the first sprouts just showing. Such tubers can be depended upon, if suitable conditions prevail, to start quickly when planted and to make a vigorous growth.

The general practice among southern growers of securing seed from the North involves in the absence of suitable storage conditions one of two things: Either getting the seed potatoes late in the fall and holding them over in dugouts, pits, or cellars, with consequent sprouting before planting, or the risk of having the seed chilled, frozen, or overheated while in transit in midwinter. In the writer's opinion the greatest need of the large southern truck grower at present is that of suitable storage facilities for handling fall shipments of seed potatoes. As a purely economic proposition the proposed change ought to commend itself. In probably nine cases out of ten the difference in first cost of these potatoes as between fall and midwinter shipments would more than offset the extra cost of storage, while the added security from danger of chilling or freezing the shipment would still further compensate the grower.

For further particulars on storage, consult Farmers' Bulletin 847, entitled "Potato Storage and Storage Houses."

LARGE COMPARED WITH SMALL SEED TUBERS.

In seasons of short production and consequent high prices for table stock, the question is frequently raised as to the advisability of using the small unsalable tubers for seed. The answer to this question is that it is always unsafe to use small tubers for seed purposes unless one is absolutely certain that they have been produced by healthy, vigorous, and productive plants. As a result of some experimental study of this question by Ballou and Gourley [3] it was found that the use of large tubers gave—

(*a*) A very heavy, perhaps almost total, percentage of the high-producing strains.
(*b*) A heavy percentage of the average or moderate-yielding strains.
(*c*) A very small percentage of the inferior or low-producing strains.

[3] Ballou, F. H., and Gourley, J. H. I. The status of the potato growing industry in Ohio. II. Seasonal notes on potatoes. Ohio Agr. Exp. Sta. Bul. 218, p. 587. 1910.

The use of small potatoes gives—

(*a*) A very insignificant percentage of the superior or high-yielding strains.
(*b*) A small percentage of the average or moderate-yielding strains.
(*c*) A very heavy, almost total, percentage of the low-yielding or inferior strains.

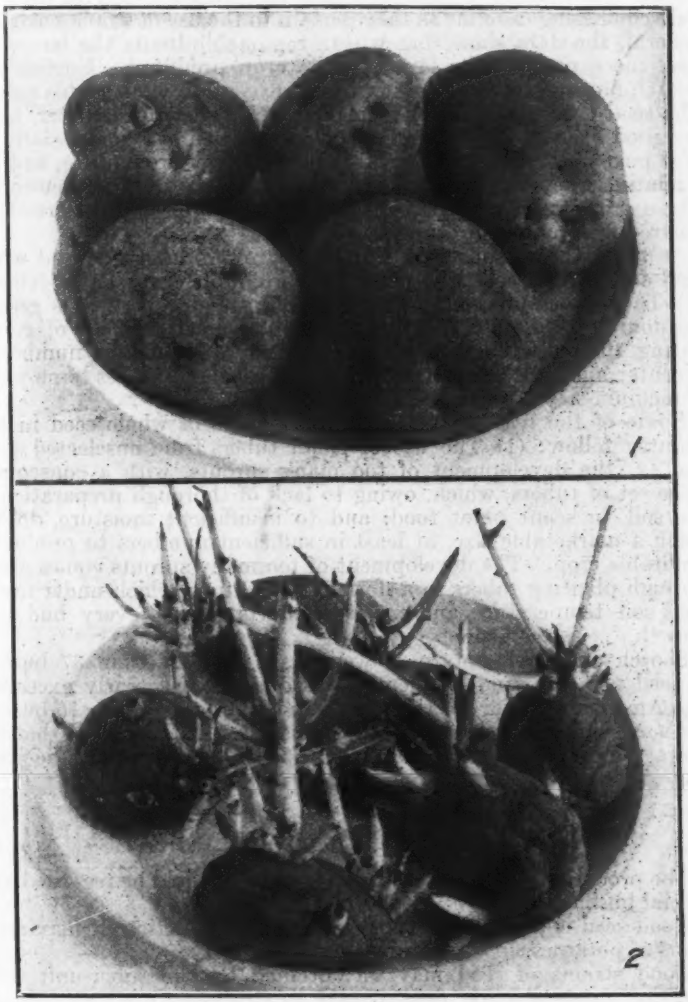

FIG. 7.—Potatoes for seed purposes, showing different stages of germination: 1, Desirable; 2, undesirable.

The use of small seed potatoes is only permissible when they are known to have been produced by strong, healthy, and productive plants. It is never advisable to use small tubers from the general mass produced from unselected stock.

WHOLE COMPARED WITH CUT SEED.

Considerable attention has been paid to the subject of whole versus cut seed at various times by the State agricultural experiment stations. The data accumulated in these investigations are for the most part conflicting in so far as they pertain to the use of whole seed. In general, the data show that within reasonable limits the larger the seed piece planted the larger is the crop produced. English and Scotch potato growers almost without exception plant whole tubers. The seed used usually runs from 1¼ to 2¼ inches in diameter, being screened out of a crop which as a rule has been grown especially for seed purposes. They are harvested before they are mature, and but a relatively small proportion of the crop exceeds the size mentioned. These growers believe that an earlier and more vigorous growth is secured from immature tubers.

Some of the reasons why European growers have adopted whole seed and are succeeding in producing profitable crops are as follows: (1) They are assured of an almost perfect stand; (2) there is greater freedom from disease; (3) the almost universal practice of germinating their seed before planting insures a minimum number of sprouts; and (4) the greater fertility of their land makes large yields of medium-sized tubers possible.

Some of the reasons for failure in the use of whole seed in this country follow: (1) The use of small tubers from unselected stock and (2) the development of too many sprouts, with a consequent large set of tubers, which, owing to lack of thorough preparation of the soil, to scant plant food, and to insufficient moisture, do not reach a marketable size, at least in sufficient numbers to produce a profitable crop. The development of too many sprouts comes about through planting tubers in a dormant condition, which under favorable soil temperature and moisture starts almost every bud into growth.

Scotch and Irish potato growers plant not less than 37 bushels of seed per acre, and frequently this quantity is greatly exceeded. The American grower, on the other hand, plants from 7 to 16 bushels per acre, with an average of 9 to 11 bushels. It is believed that the average potato production of the United States would be very materially increased if a larger quantity of seed were used.

SUMMARY.

The production of high-grade seed potatoes should be regarded as a special business.

Good seed is a determining factor in the production of maximum crops of potatoes.

Good strains of seed may be obtained by the tuber-unit, hill-selection, mass-selection, field-roguing, or strain-test methods through the process of elimination.

Like produces like. If tubers from unproductive, weak, or diseased plants are planted, a poor harvest will be reaped. Use seed from productive plants.

Purity of seed stock is an essential quality of good seed. Serious losses are sustained by the grower through mixtures.

Good seed can not be produced unless the growing plants are well cared for and the strain of seed planted was a good one.

A more liberal use of good seed would materially increase the average production per acre.

All seed should be disinfected before planting.

Experimental evidence does not indicate that whole seed is superior to cut seed, at least so far as it relates to the United States.

Good storage facilities are essential to insure sound, firm seed at planting time.

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FARMERS' BULLETIN No. 1332 rev.
May 1925

SEED POTATOES AND HOW TO PRODUCE THEM

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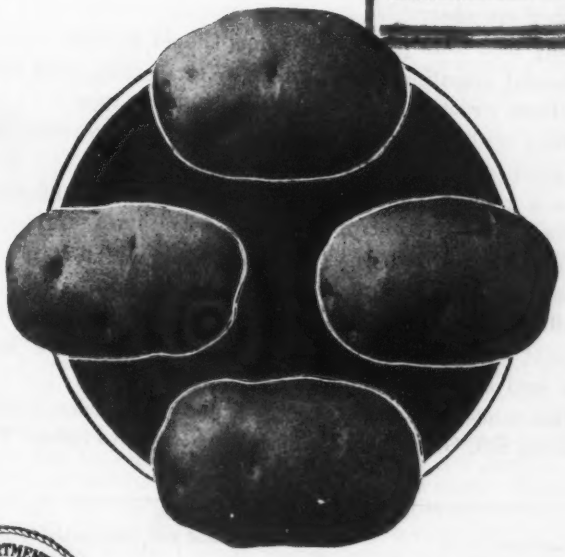

XUM

THE AVERAGE PRODUCTION per acre of potatoes in the United States is very much lower than in Canada, Great Britain, and European countries outside of Italy.

One of the reasons for the lower production in the United States is that less attention has been given to the character of the seed. Good seed is one of the determining factors in the production of maximum crops of potatoes.

The use of high-grade seed would increase the returns from the potato crop of the country by many millions of dollars.

The quality of the seed may be improved through the removal of all diseased, weak, or off-type plants as soon as they are observable.

Only seed from productive plants should be used.

Careful attention should be given to securing seed that is free from varietal mixture and that is true to type.

Good seed can not be produced unless the growing plants are given good cultural attention.

As a rule the quantity of seed used is not sufficient to produce a maximum crop.

From 15 to 18 bushels of seed should be used per acre instead of 9 to 11, as at the present time.

All seed stock should be disinfected before planting.

Good storage conditions are essential to insure sound, firm seed at planting time.

This bulletin is a revision of and supersedes Farmers' Bulletin 533, Good Seed Potatoes and How to Produce Them.

Washington, D. C. Issued May, 1923; revised May, 1925

SEED POTATOES AND HOW TO PRODUCE THEM.

By WILLIAM STUART, *Horticulturist, Office of Horticultural Investigations, Bureau of Plant Industry.*

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YIELDS OF POTATOES.

A STUDY of the statistical data upon potato crop production in the United States for the last 55 years[1] reveals the interesting fact that relatively little gain in production per acre has been made during this period. To partially minimize seasonal variations in yield per acre the 55-year period has been divided into eleven 5-year cycles and the average production of each cycle compared. During the first 5-year cycle, 1868–1872, the average yield per acre was 94.5 bushels, while in the last 5-year period it was 98.9, or a gain of approximately 4.4 per cent. The averages for the eleven 5-year cycles are 94.5, 88.1, 77.9, 76.7, 74.0, 79.9, 82.2, 96.3, 96.5, 96.0, 98.9 bushels per acre, respectively. A study of these data shows that there was a very appreciable and more or less gradual decline in production per acre during the second, third, fourth, and fifth cycles, or from 1875 to 1892, inclusive, and that during the next three cycles there was a decided increase, the fifth cycle showing a slight increase over the first cycle. From this period until 1908 to 1922 the increase has been a very nominal one, unless we choose to regard the 1918 to 1922 performance as indicating a permanent improvement in the per acre production of potatoes. From the data presented it is evident that the slight gain in average yield per acre (4.4 per cent) in the last of the eleven 5-year cycles over that of the first cycle is not sufficient to account for the increased production of potatoes in the United States. The total average bushel production in the United States for the years 1868 to 1872 was 117,745,800, while in the last 5-year period (1918–1922) the average production was 390,615,600 bushels, or an increase over the first period of more than 231 per cent. During this same period the increase in acreage devoted to potato production has been more than 217 per cent. These data show conclusively that increased production in the United States during the last 55 years has been almost entirely due to increased acreage rather than to any material improvement in cultural practices resulting in larger yields per acre.

Table 1 and the accompanying diagrams (figs. 1 to 3) show the average acre yields, the farm price per bushel, the acreage grown,

[1] The statistical data upon which these studies are based were obtained for the years 1868 to 1888 from the United States Department of Agriculture Yearbook for 1917, p. 657; for 1889 to 1895 from the 1920 Yearbook, p. 617; for 1896 to 1920 from the 1921 Yearbook, p. 583; and for 1921 to 1922 from the December 23, 1922, issue of the United States Department of Agriculture Weather Crops and Markets publication, p. 565.

and the total production of potatoes, while Figure 4 shows the population of the United States during the eleven 5-year cycles studied. In the construction of these diagrams it has not been feasible to employ the same scale in any two of them, owing to the great difference in the magnitude of the figures treated. A careful study of the first diagram (fig. 1), in which the acreage yield and

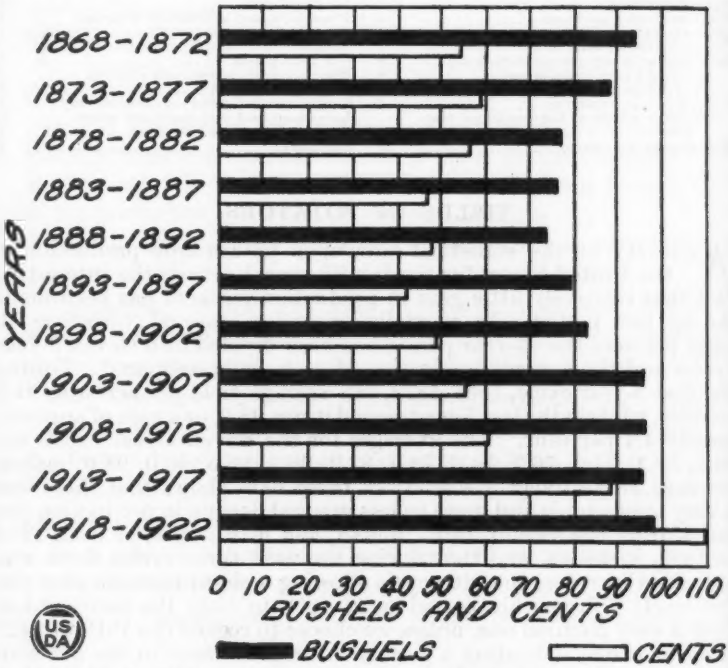

FIG. 1.—Diagram showing the average number of bushels per acre and the average farm price per bushel of potatoes grown in the United States by 5-year periods from 1868 to 1922.

farm price per bushel are given, shows that the acreage-production curve, if drawn on the chart, would somewhat resemble the curve of a scimitar blade, in which the extreme ends of the blade represent the maximum yields for each half of the curve.

TABLE 1.—*Averages of acreage, production, and farm values of potatoes in 5-year periods from 1868 to 1922, inclusive.*

5-year period.	Number of acres.	Production (bushels).		Farm value on Dec. 1.	
		Total	Per acre.	Total.	Per bushel (cents).
1868 to 1872	1,246,200	117,745,800	94.5	$64,123,600	54.5
1873 to 1877	1,529,800	134,773,200	88.1	68,665,600	50.9
1878 to 1882	1,934,200	150,706,200	77.9	85,547,200	56.8
1883 to 1887	2,284,000	175,197,800	76.7	82,295,000	46.9
1888 to 1892	2,633,800	194,939,400	74.0	93,012,600	47.7
1893 to 1897	2,900,400	231,757,800	79.9	95,258,400	41.1
1898 to 1902	2,968,200	243,866,400	82.2	117,671,600	48.3
1903 to 1907	3,213,200	309,568,200	96.3	170,652,800	55.1
1908 to 1912	3,644,400	351,793,800	96.5	213,038,200	60.6
1913 to 1917	3,812,400	366,045,600	96.0	322,292,400	88.0
1918 to 1922	3,948,400	390,615,600	98.9	425,975,400	109.1

The gradual decline in yields during the first half of this period is thought to be largely due to the following factors:

The ravages occasioned by the Colorado potato beetle during the early period of its invasion of the eastern United States.

The financial depressions of 1877 and 1893, which brought about a well-marked decline in agriculture in New England, New York, and the other heavy potato-producing areas of the northeastern United States.

A gradual depletion of soil fertility.

Of the factors which have checked the downward tendency and contributed most largely toward a return to the old production level the following are thought to have been most potent:

The influence of the agricultural experiment stations, agricultural colleges, and the United States Department of Agriculture through experimentations, demonstration, and the dissemination of literature.

The influence of the Bordeaux-mixture treatment in the control of fungous diseases affecting the potato.

The development of special potato-growing sections, as, for example, Aroostook County, Me., the Atlantic Coastal Plain trucking region, the Greeley and Carbondale districts of Colorado, and many other areas, in which the average yield is approximately from two to three times the general average for the United States.

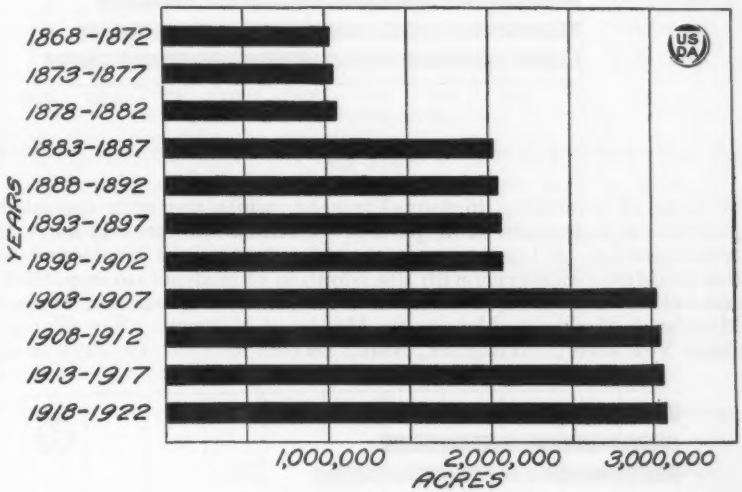

FIG. 2.—Diagram showing the average potato acreage of the United States by 5-year periods from 1868 to 1922.

Figures 1 to 4 show a comparison of the relation of increased production to a constantly increasing population. The diagrams show that under normal conditions production is keeping pace with population. Crop shortages are, therefore, the result of abnormal or unfavorable conditions.

In comparing the average crop production of potatoes in the United States with that of Great Britian, one is impressed with the fact that generally speaking we have much yet to learn before we can raise our average to that of that country. During the years 1901 to 1910, inclusive, the average acre yield in Great Britain was approximately 200 bushels, while that in the United States was not quite 93 bushels.

Of the many causes which produce a low average potato yield in this country, poor seed is thought to be important. The American potato grower pays too little attention to his seed potatoes. European growers pay very strict attention to the quality and quantity of seed they use. This has led to the differentiation of the potato growers into seed and crop specialists. The seed specialist makes a

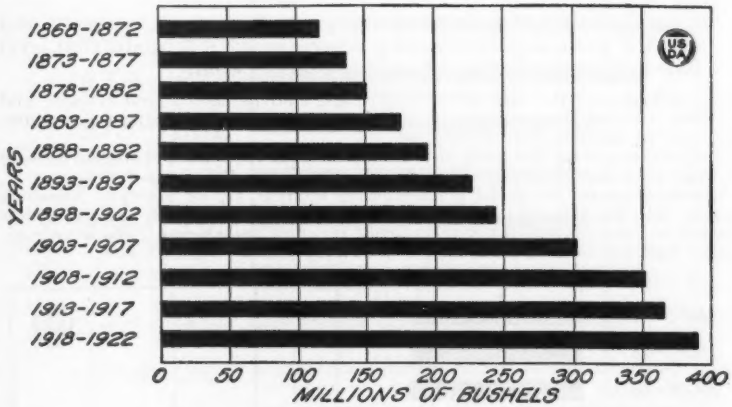

FIG. 3.—Diagram showing the average potato production of the United States by 5-year periods from 1868 to 1922.

business of producing high-quality seed, while the crop specialist produces a high-grade table potato. Until rather recently no such differentiation, at least to any marked extent, could be claimed in this country. However, with the adoption of seed-potato inspection and certification in California, Colorado, Idaho, Kentucky, Maine, Maryland, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Oregon, Pennsylvania,

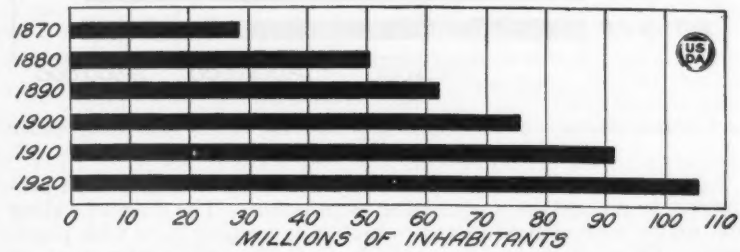

FIG. 4.—Diagram showing the population of the United States by decades from 1870 to 1920.

South Dakota, Vermont, Washington, Wisconsin, Wyoming, and all of the Canadian Provinces, groups of seed-potato growers are gradually being evolved. A further stimulus to those who are engaged in the production of seed potatoes is the increasing demand for good seed stock at prices which are sufficiently remunerative to well repay the grower for the extra care given to the crop.

WHAT CONSTITUTES GOOD SEED.

Two factors are involved in the consideration of good seed potatoes: (1) The physical or outward appearance of the tubers and (2) the heritable or transmissible characters of the stock. The first involves the purity and maturity of the stock, uniformity in size and shape of the tubers, brightness of skin, firmness of flesh with first sprouts just showing, and freedom from scab, Rhizoctonia, late-blight, or other tuber-decay diseases. The second factor deals with nonobservable characters and is by far the more important one, as it involves the presence or absence of the virus diseases causing mosaic, leaf-roll, spindle-tuber, streak, and yellow dwarf. Freedom from the virus diseases is an important consideration and can only be assured through personal inspection of the growing plants from which the seed was obtained or by the purchase of reliably certified stock. If in any given year it were possible to plant the entire potato acreage of the United States with first-class seed stock the total production would be increased from 10 to 25 per cent. Based on the average production for the 5-year period from 1918 to 1922, this increase would represent from 39 to 97½ million bushels, or an increase in money value of $40,333,000 to $106,333,000.

CERTIFIED AND UNCERTIFIED SEED.

The rapid increase in acreage and production of certified seed potatoes, together with the premium over uncertified seed demanded by the grower for such stock, has made it necessary to demonstrate its superiority over ordinary seed. In the early and consequently developmental period of seed certification the producers' claims of superiority were not sufficiently well supported by experimental evidence to make them convincing. To-day there is abundant evidence of the general superiority of certified over uncertified seed potatoes. In a recent paper presented at the 1924 annual meeting of the Potato Association of America, H. C. Moore, of the Michigan Agricultural College, submitted data covering actual comparative tests by a large number of independent investigators, as shown in Table 2.[2]

TABLE 2.—*Comparative tests of potato yields, showing the advantage of using certified seed.*

Location of tests.	Number of tests or reports.	Average increase in yields per acre (bushels).	Location of tests.	Number of tests or reports.	Average increase in yields per acre (bushels).
Canada (8 Provinces)	15	88	Michigan	314	73
Connecticut	144	53	Missouri	46	43
Delaware	21	83	Montana	2	219
Indiana	9,740	44	Nebraska	64	141
Illinois	15	47	New York	68	76
Kansas	11	41	Ohio	168	48
Kentucky	220	42	Oregon	3	150
Louisiana	31	42	Pennsylvania	87	41
Maine	279	83	South Carolina	8	31
Massachusetts		75			

These and many other data serve to emphasize the value of high-grade seed. They also indicate the general superiority of certified over noncertified stocks as a source of good seed.

[2] Moore, H. C. Evidence that certified seed is improved seed. *In* Proc. 11th Ann. Meeting, Potato Assoc. America, 1924, p. 28. 1925.

UNIFORMITY IN SIZE AND SHAPE OF TUBERS.

Under normal conditions of growth many present-day commercial varieties are very variable in size and shape of tuber. To some extent both size and shape are determined by the character of the soil, rate of planting, fertilization, and cultural care given the growing crop. Inheritance, however, plays a very important part. Most varieties contain within themselves distinct varietal strains which when isolated are much more uniform in respect to size and shape than the variety itself. Other things being equal, the variety or varietal strain that produces the greatest number of fair-sized shapely tubers and the smallest number of ill-shaped and small tubers should prove the most valuable, because it involves less waste to both the grower and the consumer. It is particularly important at present that such strains be developed, because there is an increasing demand for fancy table stock to satisfy the requirements of a large and discriminating class of consumers who are insisting on greater uniformity in size and shape and are willing to pay a premium on such grades.

DEVELOPMENT OF HIGH-GRADE SEED POTATOES.

The successful production of high-grade seed potatoes is very largely dependent upon the following factors: (*1*) *Starting with a good strain;* (*2*) *the proper treatment of the seed;* (*3*) *thorough preparation and proper fertilization of the soil;* (*4*) *the following of the best cultural practices, including protection against insect and fungous pests;* (*5*) *the elimination of all mixtures and all diseased or weak plants; and* (*6*) *the careful harvesting and proper storage of the crop.*

SECURING A GOOD STRAIN OF SEED.

If the strain of seed you are using is lacking in vigor, it is generally advisable to discard it and purchase a new lot from some reliable grower whose stock you have reason to believe is superior to yours. This suggestion is made as the result of a rather wide experience in trying to improve poor strains of potatoes through selection methods. Such attempts have usually resulted in failure, and it is felt that as a rule much more satisfactory progress can be made by starting with a new strain. Further improvement can usually be secured through selection.

SEED-POTATO IMPROVEMENT BY SELECTION.

The improvement of seed potatoes by selective processes has long engaged the attention of the potato grower. Recent experimental evidence seems to indicate that the possibilities of improving potato seed stock by selective processes alone are not as great as many writers upon this subject have claimed. To those who have devoted much time and effort to the improvement of the potato by selection it would appear that the chances of finding superior yielding true-to-type strains within a variety are not as great as has been believed. The chief advantages to be derived from seed-potato selection practices are the elimination of diseased and weak plants and the removal of varietal mixtures.

IMPROVEMENT PRACTICES.

Five improvement practices may be used in securing a high-yielding and commercially desirable strain of potatoes: (1) The tuber-unit method, (2) hill selection, (3) mass selection, (4) field roguing, and (5) strain testing.

In early editions of Farmers' Bulletin 533 considerable emphasis was laid upon the tuber-unit method of seed-potato improvement; subsequent experiences of the writer and others have indicated that this method is not as satisfactory or as practical in operation as the other four methods suggested. It is thought desirable, however, to briefly describe the tuber-unit method because some of its processes are applicable to other selection methods.

TUBER-UNIT METHOD.[3]

The tuber-unit method, as now generally understood, consists in selecting from the seed bin before planting time a considerable number of the most perfectly shaped tubers ranging from 6 to 8 ounces in weight. When planted, these tubers are quartered, as dropped, into four as nearly equal parts as possible, by splitting the bud-eye cluster twice from seed to stem end of the tuber. In other words, the tuber is cut through its longitudinal axis. The four pieces of each tuber are dropped consecutively in the row at a distance of from 10 to 12 inches apart in the furrow. All tubers showing discoloration of the flesh or other evidence of disease should be rejected. By allowing an additional spacing between each set of fours, the four plants from each tuber are definitely isolated from adjoining ones and the grower can readily observe any variation in vigor and uniformity between the various units planted. This method also enables him to detect any mixtures that may occur in the variety. All mixtures should at once be removed. By marking the units which appear to be the most uniform in size, vigor, and type when the plants are still in vigorous growth, the first step in selection has been accomplished. At digging time the product of each unit is separately harvested and a further selection made from the marked units of all tubers which most nearly approach the size, shape, and smoothness desired. The selected tubers of each unit should be separately placed in small sacks, preferably cotton or burlap, numbered with both field and unit numbers, and stored to await further examination. The final examination should produce data on the number and weight of merchantable and unmerchantable tubers and their general conformity in size, shape, and smoothness of the type desired. From each of the units retained 10 of the best tubers should be selected for the next season's planting.

It is desirable to maintain the study of each selection on the tuber-unit basis the following season, because it permits a more accurate comparison of the behavior of each. The 10 selected tubers from each original unit will give 40 plants for study the second year. All selections which do not produce a reasonably uniform lot of plants should be marked for rejection. At harvest time the progeny of each selec-

[3] For further information concerning the arrangement of a tuber-unit selection plat and a convenient system of note taking, see Stuart, William, The "tuber-unit" method of seed-potato improvement. U. S. Dept. Agr., Bur. Plant Indus. Cir. 113, pp. 25-31, 2 fig. 1913.

tion should be kept by itself and the same data recorded as those taken on the crop grown from the original tuber unit. Only the product from such 40-hill rows as meet the most rigid requirements should be retained. The further conduct of the work will consist in the multiplication of the selected strains for field planting and the elimination of weak plants.

HILL SELECTION.

The hill-selection method consists in marking the most promising plants during the growing season and at harvesting time saving only those which give the greatest promise. (Figs. 5 and 6.) The progeny of each hill should be kept separate and the same data taken as outlined for the tuber unit. Plant on the tuber-unit or progeny-

FIG. 5.—Progeny of a mosaic-infected potato plant of the Triumph variety on the left (*A*) and of a healthy plant on the right (*B*). Bin selection of such seed would result in taking at least two tubers from the mosaic plant. If small tubers were used all would come from diseased plants. In hill-selection work the progeny of plant B should be saved.

row basis the following season. For the sake of uniformity a definite number of tubers (five or more) should be planted from each hill selection. From this point on, follow the methods given in tuber-unit work.

MASS SELECTION.

Mass selection differs from hill selection in only one respect, which is that the tubers from the individually selected plants are not kept separate. Generally those who practice mass selection do not go to the trouble of marking promising individual plants during the growing season, but simply go through the field before harvesting the whole crop and dig by hand as many plants as may be desired to secure the necessary quantity of seed that show the desired vigor and stem characters thought to be correlated with productiveness, trueness to type, and uniformity in size of tubers of the particular variety grown.

FIELD ROGUING.

Improvement of the seed stock through field roguing consists in the removal of all diseased, weak, off-type, or varietal-mixture plants during the growing season. The successful removal of such plants does not necessarily involve an intimate knowledge of the various diseases affecting the potato, but it does require that the person doing the roguing be able to tell whether a plant is normal or abnormal in appearance. A sufficient field area should be rogued the first year to provide the quantity of seed necessary to plant the full acreage to be grown the ensuing season. The area to be rogued should be gone over at least three times during the growing season, to insure the removal of all plants affected with transferable diseases, such as mosaic and leaf-roll, as soon as their presence can be detected. In the field-roguing method no attempt is made to select the progeny of individual plants at harvesting time, the whole crop being dug and all desirable seed stock gathered and stored in bulk.

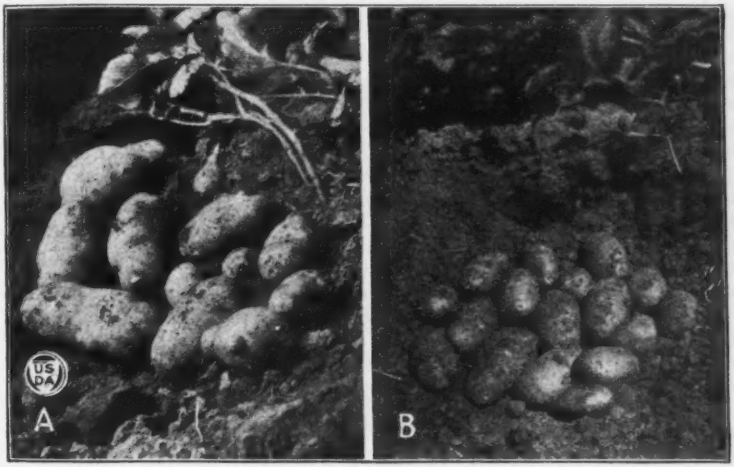

FIG. 6.—Progeny from abnormal (*A*) and normal (*B*) plants of the Russet Burbank potato. Plant A is known in the West as a degenerate or run-out plant, and the disease with which it is affected is probably identical with that recently termed "spindle tuber." It is a communicable disease and may become serious. In hill-selection work the progeny of plants such as *B* should be saved.

STRAIN TESTING.

The improvement of seed potatoes by the strain test, or, as it might more properly be termed, the "source-of-seed test" method, consists in securing as many as possible desirable lots of seed stock of the same variety from different growers throughout a given district or State, or even from various States, and carefully studying their behavior when grown side by side under identical soil and cultural conditions. Experimental studies by this method of seed improvement have demonstrated that some lots or strains of seed stock are far superior to others; in fact, differences in yield of more than 100 bushels per acre have been noted between the lowest and highest yielding strains. Furthermore, it has been conclusively demonstrated by numerous trials that these yields were not accidental, but that in practically every instance the high-yielding strains have consistently given larger yields wherever tested.

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The improvement of seed stock by this method does not consist in the actual isolation and development of a strain from a given variety, but rather in locating, as it were, by comparative tests the really superior sources of seed stock. The actual improvement accomplished is measured by the success attending one's efforts in getting live, up-to-date growers to discard their inferior strains and purchase the superior one, as shown by the tests made.

The practical operation of such a movement may be best emphasized by stating that in 1921 over 100 potato growers in Wisconsin grew seed stock of a superior strain of Triumph potatoes located in this manner in 1918.

It should be remembered that whatever selection practice is pursued the fields devoted to the production of high-quality seed must be carefully rogued if the vigor of the seed stock is to be maintained.

RELATIVE MERITS OF THE PRECEDING PRACTICES.

In the preliminary discussion of seed-potato improvement in this bulletin it is intimated that the chance of securing a superior strain of a commercial variety of potato through selective processes is not as great as earlier writers on this subject have claimed. A careful consideration of all the experimental evidence thus far presented would seem to justify the conclusion that the tuber-unit method of seed-potato improvement does not afford as satisfactory a starting point for selection work as the hill-selection method. The evidence at hand would also seem to indicate that neither of these practices is to be commended to the average grower of seed potatoes, as both methods involve an expenditure of a greater amount of time and effort in properly observing the details necessary to their successful application than can reasonably be expected of such a grower. The tuber-unit and hill-selection methods can only be recommended to those growers who have ample time or means to undertake these studies and to those experiment-station investigators who have the facilities necessary for carrying on such work.

The "mass-selection" and the "field-roguing" methods are more nearly adapted to the average grower, as neither method involves the growing and keeping separate of a large number of individual selections. Both are so simple of execution that any person of ordinary intelligence can practice them.

Strain testing involves a somewhat more elaborate plan of operation, in that it requires the purchasing and growing of several strains of a given variety under as nearly identical conditions as it is possible to supply. This method of seed-potato improvement may be best undertaken by the type of men suggested for the conduct of the tuber-unit and hill-selection systems. The average grower should avail himself of the findings of those engaging in strain testing and purchase his seed from those growers having the most desirable seed stock, as demonstrated by such tests.

REQUIREMENTS FOR SUCCESS.

The only requirements for the successful practice of the first two methods of seed selection are a reasonable degree of painstaking effort on the part of the grower, some 12-inch garden labels, a small pair of balances, a sufficient number of suitable small sacks, and a

safe place in which to store the selected tubers until required for the next season's planting. In addition to this, the grower should have a breeding plat in which each season's selections can be developed up to the point of field-planting stock. This selection or seed plat should be located at as great a distance from the commercial potato field as possible in order to secure the greatest degree of isolation that is feasible. Heretofore the problem of isolation has not received due consideration. This was largely owing to the fact that the seriousness of such diseases as mosaic, leaf-roll, curly-dwarf, streak, and spindle-tuber has only recently come to be recognized. The fact that all of these diseases are readily transmitted from diseased to healthy plants through the instrumentality of plant lice, or aphids, and the further fact that as yet there is no reliable information as to the distance insects may transport these diseases suggest as complete isolation of the seed plat as possible. The latest suggestion in regard to the production of seed potatoes under isolation is that each variety be grown separately, as it has been found that stock of certain varieties supposed to be free from mosaic have served as disease carriers to more susceptible varieties. For example, it is not desirable to grow the Irish Cobbler adjacent to the Green Mountain intended for certification, as the former may carry the mosaic virus without expressing it. The danger from contamination of the healthy Green Mountain strain by the Irish Cobbler is considered sufficiently great by some seed-certification agencies to cause them to refuse to consider stock thus grown as eligible for certification. The ultimate success of the seed plat in so far as the elimination of tuber-borne diseases is concerned rests largely upon the ability of the grower to recognize diseased plants and the promptness with which they are removed from the seed plat and destroyed. Frequent and thorough inspections of the seed plat are necessary to insure the largest possible reduction of diseased plants and to reduce the transmission of disease from diseased to healthy plants.

SEED TREATMENT.

It is impossible to produce high-grade seed potatoes if the seed planted is infected with disease organisms capable of infecting the crop. The disinfection of the seed potatoes is therefore necessary if the best results are to follow. The two diseases for which seed potatoes are ordinarily treated are common scab and black scurf, or Rhizoctonia. The two disinfecting agents recommended for such treatment are formalin and corrosive sublimate (mercuric chlorid, or bichlorid of mercury). Formalin is as effective against the common scab as corrosive sublimate, but it does not give as good results in the destruction of the black-scurf fungus. When the latter is present on the tubers corrosive sublimate should be used. The formulas recommended for these two disinfectants are as follows:

(1) Formalin, 1 pint.
Water, 30 gallons.

(2) Corrosive sublimate, 4 ounces.
Water, 30 gallons.

If the formalin treatment is selected the seed potatoes should be soaked in this solution from one-half to 1½ hours. Recent experiments by Dr. I. E. Melhus, of the Iowa Experiment Station, indicate that an immersion of the seed potatoes for 2 minutes in a formalin solution of twice the stength mentioned heated to a temperature

of 122° F. and covered for an hour after their removal from the hot liquid is just as effective as the longer treatment in the cold solution.

When the corrosive-sublimate solution is used, the length of the immersion should be governed by the condition of the tubers and their freedom from, or the severity of, the black-scurf infection. If the tubers are dormant and they are more or less infected with the sclerotia of the black scurf the treatment may be prolonged to 1½ or 2 hours. If they have started to germinate and are reasonably free from black scurf the period may be shortened to a half hour or less.

The treated tubers should on no account be allowed to come in contact with such receptacles as old sacks and barrels in which diseased seed has been handled, as they are almost certain sources of reinfection.

PREPARATION AND FERTILIZATION OF THE SOIL.

Strong, vigorous plants can not be produced on land that has been poorly prepared or that is deficient in available plant food. Seed potatoes should be grown on land that has been deeply plowed and thoroughly prepared to receive the seed. It should be well supplied with organic matter and available plant food. A clover or alfalfa sod furnishes the organic matter and considerable of the plant food. Barnyard manures or commercial fertilizers, or both, will supply the additional plant food necessary to produce a good crop

CAREFUL CULTURAL PRACTICES.

The vigor of the seed stock produced is to a large extent dependent on the care given to the growing crop. Uniformity in the size of the tubers is to a large extent governed by the rate of planting. Closer planting should be practiced in the growing of seed than of table stock. Some growers in Aroostook County, Me., space their rows from 32 to 36 inches apart and the plants in the row 8 to 12 inches. The crop should be cultivated as frequently as may be necessary to provide the most suitable growing conditions.

Every effort should be made to protect the plants from injury by insect or fungous pests. Leaf-eating insects can be effectively controlled if the plants are thoroughly sprayed with arsenical poisons; sucking insects with contact solutions, such as kerosene emulsion and nicotine; and fungous diseases, such as the early and late blights, with Bordeaux mixture. In every operation it should be remembered that whatever contributes to the health of the plant increases the vigor of the seed stock produced.

ELIMINATION OF VARIETAL MIXTURES AND DISEASED OR WEAK PLANTS.

The vegetable-seed growers employ the term "roguing" to denote the process of removing all mixtures or off-type plants from the seed plat. As this term, when understood, is a brief and yet sufficiently descriptive way of indicating the process of eliminating all undesirable plants or "rogues," it is proposed to use it in this connection.

It is an easy matter to rogue a seed-improvement or selection plat during the growing season. Varietal mixtures are more easily detected when the plants are in bloom. Weak plants are usually apparent in the early stages of their growth, as are also certain types of diseases, such as mosaic and black-leg, although both may appear later. Plants infected with Rhizoctonia and Fusarium are usually

not apparent until the latter part of the growing season. It is evident from these statements that in order to rogue the seed plat thoroughly it is necessary to make two or three examinations of the field or plat during the growing season. Further roguing should be done when the crop is harvested by discarding the progeny of all low-producing plants. (Fig. 5, *A*.)

MONETARY VALUE OF GOOD SEED POTATOES.

The producer of high-grade seed potatoes is justly entitled to a fair monetary return for the special efforts he has made to produce quality seed stock. This is especially true where a seed plat is maintained year after year and the crop has been officially inspected and passed by a duly authorized seed-certification inspection officer. Just what increase in price over ordinary stock one is entitled to receive for such efforts and for the inspection fees involved is not an easy matter to determine. It is believed that a premium of 50 cents per bushel over the market price of table stock of the same variety is ordinarily sufficient to amply repay the grower. Opinions, however, will differ upon this point. At the present time the price of certified seed stock varies all the way from $1 to $3.50 per hundredweight—60 cents to $2.10 per bushel.

IMPORTANCE OF TUBER SHAPE.

Reasonable trueness of the tubers to varietal type is generally demanded by the purchaser of certified seed. And most writers who have dealt with the subject of good seed have always placed strong emphasis upon the importance of its being true to type. Rather recently, however, some scientific as well as practical growers have been disposed to regard tuber shape as being of less importance than has been previously supposed. They have come to regard tubers that have departed from the type as a result of unfavorable environmental conditions as being satisfactory for seed purposes.

As a result of a long-continued preachment of the undesirability of slightly off-type tubers for seed purposes many cars of otherwise high-grade seed stock have been annually rejected by the southern truck grower. This is particularly true in the case of conspicuously flattened and somewhat elongated tubers of the Irish Cobbler variety. The Irish Cobbler grower in the South has come to demand roundish tubers and is suspicious of the purity of seed stock containing flattened and somewhat elongated tubers and generally protests their acceptance as strictly first-class seed stock. In fact, he is inclined to regard the off-type tubers as Green Mountain. The only obvious way of correcting these firmly rooted convictions is to demonstrate experimentally that off-type tubers resulting from unfavorable soil, cultural, or climatic conditions are no more likely to produce off-type progeny than are normal-shaped ones. This statement, however, does not apply to off-type tubers resulting from disease; such tubers should not be planted. The spindle-tuber recently recognized by pathologists as a communicable disease is very similar in its method of transmission to that of leaf-roll and the mosaic disease. Figure 6, *A*, represents a fairly good example of spindle tubers. It is important, therefore, in the purchase of somewhat off-type seed potatoes to know whether the change in shape is really due to unfavorable environmental factors and not to disease.

CAREFUL HARVESTING AND STORAGE OF THE CROP.

The average grower does not fully appreciate the importance of using every means to prevent the mechanical injury of the tubers during the process of harvesting and storing. If the crop is grown on land containing a plenteous admixture of small stones the tubers are almost certain to be more severely injured in harvesting than when grown in a sandy loam soil. Hand digging is not always feasible, but it is believed that where small stones abound in the soil it will be desirable to harvest the home seed plat by hand. Much injury will be avoided if the seed stock designed for planting the field plat of the ensuing year is picked directly into crates in which it is allowed to remain throughout the storage period.

The storage conditions necessary to insure vigorous seed at planting time are more easily provided in the North than in the South. In the former region a well-constructed cellar, pit, or cave serves reasonably well. The main thing is to keep the room temperature sufficiently low to retard germination. The ideal seed tuber is one which has not wasted any of its stored-up energy by excessive loss through sprouting. (Fig. 7.) It should be firm, with the first sprouts just showing. Such tubers can be depended upon, if suitable conditions prevail, to start quickly when planted and to make a vigorous growth.

The general practice among southern growers of securing seed from the North involves in the absence of suitable storage conditions one of two things: Either getting the seed potatoes late in the fall and holding them over in dugouts, pits, or cellars, with consequent sprouting before planting, or the risk of having the seed chilled, frozen, or overheated while in transit in midwinter. In the writer's opinion the greatest need of the large southern truck grower at present is that of suitable storage facilities for handling fall shipments of seed potatoes. As a purely economic proposition the proposed change ought to commend itself. In probably nine cases out of ten the difference in first cost of these potatoes as between fall and midwinter shipments would more than offset the extra cost of storage, while the added security from danger of chilling or freezing the shipment would still further compensate the grower.

For further particulars on storage, consult Farmers' Bulletin 847, entitled "Potato Storage and Storage Houses."

LARGE COMPARED WITH SMALL SEED TUBERS.

In seasons of short production and consequent high prices for table stock, the question is frequently raised as to the advisability of using the small unsalable tubers for seed. The answer to this question is that it is always unsafe to use small tubers for seed purposes unless one is absolutely certain that they have been produced by healthy, vigorous, and productive plants. As a result of some experimental study of this question by Ballou and Gourley[4] it was found that the use of large tubers gave—

(*a*) A very heavy, perhaps almost total, percentage of the high-producing strains.
(*b*) A heavy percentage of the average or moderate-yielding strains.
(*c*) A very small percentage of the inferior or low-producing strains.

[4] Ballou, F. H., and Gourley, J. H. I. The status of the potato growing industry in Ohio. II. Seasonal notes on potatoes. Ohio Agr. Exp. Sta. Bul. 218, p. 587. 1910.

The use of small potatoes gives—

(*a*) A very insignificant percentage of the superior or high-yielding strains.
(*b*) A small percentage of the average or moderate-yielding strains.
(*c*) A very heavy, almost total, percentage of the low-yielding or inferior strains.

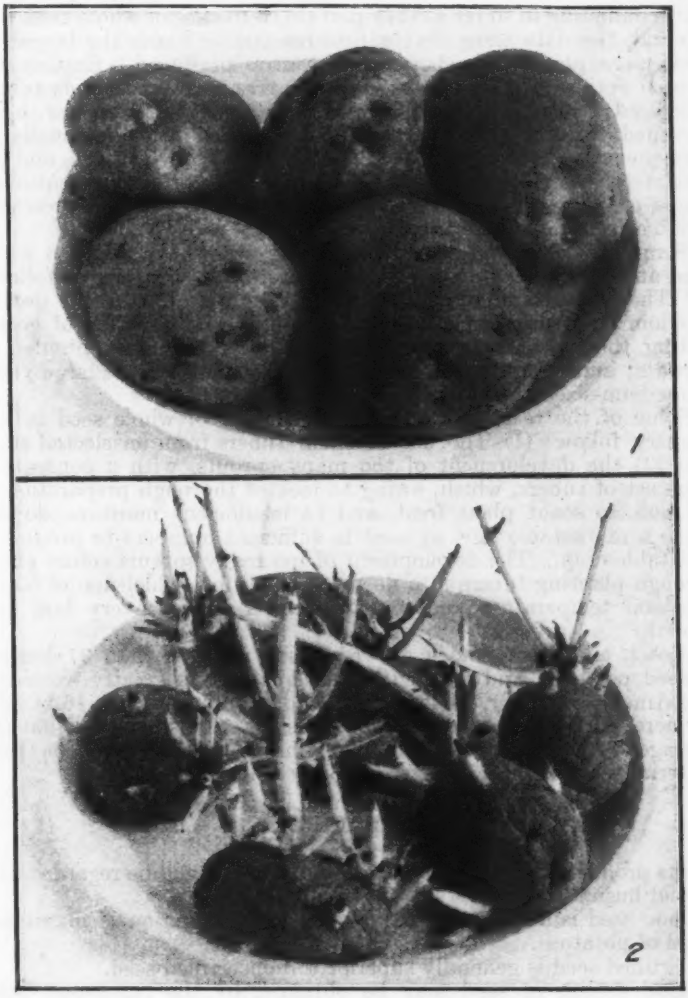

FIG. 7.—Potatoes for seed purposes, showing different stages of germination: 1, Desirable; 2, undesirable.

The use of small seed potatoes is only permissible when they are known to have been produced by strong, healthy, and productive plants. It is never advisable to use small tubers from the general mass produced from unselected stock.

WHOLE COMPARED WITH CUT SEED.[5]

Considerable attention has been paid to the subject of whole versus cut seed at various times by the State agricultural experiment stations. The data accumulated in these investigations are for the most part conflicting in so far as they pertain to the use of whole seed. In general, the data show that within reasonable limits the larger the seed piece planted the larger is the crop produced. English and Scotch potato growers almost without exception plant whole tubers. The seed used usually runs from 1¼ to 2¼ inches in diameter, being screened out of a crop which as a rule has been grown especially for seed purposes. They are harvested before they are mature, and but a relatively small proportion of the crop exceeds the size mentioned. These growers believe that an earlier and more vigorous growth is secured from immature tubers.

Some of the reasons why European growers have adopted whole seed and are succeeding in producing profitable crops are as follows: (1) They are assured of an almost perfect stand; (2) there is greater freedom from disease; (3) the almost universal practice of germinating their seed before planting insures a minimum number of sprouts; and (4) the greater fertility of their land makes large yields of medium-sized tubers possible.

Some of the reasons for failure in the use of whole seed in this country follow: (1) The use of small tubers from unselected stock and (2) the development of too many sprouts, with a consequent large set of tubers, which, owing to lack of thorough preparation of the soil, to scant plant food, and to insufficient moisture, do not reach a marketable size, at least in sufficient numbers to produce a profitable crop. The development of too many sprouts comes about through planting tubers in a dormant condition, which under favorable soil temperature and moisture starts almost every bud into growth.

Scotch and Irish potato growers plant not less than 37 bushels of seed per acre, and frequently this quantity is greatly exceeded. The American grower, on the other hand, plants from 7 to 16 bushels per acre, with an average of 9 to 11 bushels. It is believed that the average potato production of the United States would be very materially increased if a larger quantity of seed were used.

SUMMARY.

The production of high-grade seed potatoes should be regarded as a special business.

Good seed is a determining factor in the production of maximum crops of potatoes.

Certified seed is generally superior to noncertified seed.

Good strains of seed may be obtained by the tuber-unit, hill-selection, mass-selection, field-roguing, or strain-test methods through the process of elimination.

Like produces like. If tubers from unproductive, weak, or diseased plants are planted, a poor harvest will be reaped. Use seed from productive plants.

[5] Stuart, W., and others. Size of potato sets: Comparisons of whole and cut seed. U. S. Dept. Agr. Bul. 1248, 43 pp., illus. 1924.

Purity of seed stock is an essential quality of good seed. Serious losses are sustained by the grower through mixtures.

Good seed can not be produced unless the growing plants are well cared for and the strain of seed planted was a good one.

A more liberal use of good seed would materially increase the average production per acre.

All seed should be disinfected before planting.

Experimental evidence does not indicate that whole seed is superior to cut seed, at least so far as it relates to the United States.

Good storage facilities are essential to insure sound, firm seed at planting time.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

April 28, 1925.

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U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1332 rev. Oct. 1926

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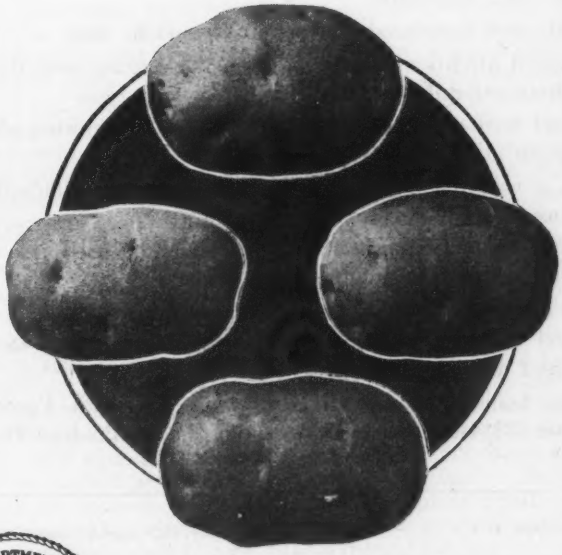
SEED POTATOES AND HOW TO PRODUCE THEM



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THE AVERAGE PRODUCTION per acre of potatoes in the United States is very much lower than in Canada, Great Britain, and European countries outside of Italy.

One of the reasons for the lower production in the United States is that less attention has been given to the character of the seed. Good seed is one of the determining factors in the production of maximum crops of potatoes.

The use of high-grade seed would increase the returns from the potato crop of the country by many millions of dollars.

The quality of the seed may be improved through the removal of all diseased, weak, or off-type plants as soon as they are observable.

Only seed from productive plants should be used.

Careful attention should be given to securing seed that is free from varietal mixture and that is true to type.

Good seed can not be produced unless the growing plants are given good cultural attention.

As a rule the quantity of seed used is not sufficient to produce a maximum crop.

From 15 to 18 bushels of seed should be used per acre instead of 9 to 11, as at the present time.

All seed stock should be disinfected before planting.

Good storage conditions are essential to insure sound, firm seed at planting time.

This bulletin is a revision of and supersedes Farmers' Bulletin 533, Good Seed Potatoes and How to Produce Them.

Washington, D. C. Issued May, 1923; revised October, 1926

SEED POTATOES AND HOW TO PRODUCE THEM.

By WILLIAM STUART, *Horticulturist, Office of Horticulture, Bureau of Plant Industry.*

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YIELDS OF POTATOES.

A STUDY of the statistical data upon potato crop production in the United States for the last 55 years[1] reveals the interesting fact that relatively little gain in production per acre has been made during this period. To partially minimize seasonal variations in yield per acre the 55-year period has been divided into eleven 5-year cycles and the average production of each cycle compared. During the first 5-year cycle, 1868–1872, the average yield per acre was 94.5 bushels, while in the last 5-year period it was 98.9, or a gain of approximately 4.4 per cent. The averages for the eleven 5-year cycles are 94.5, 88.1, 77.9, 76.7, 74.0, 79.9, 82.2, 96.3, 96.5, 96.0, 98.9 bushels per acre, respectively. A study of these data shows that there was a very appreciable and more or less gradual decline in production per acre during the second, third, fourth, and fifth cycles, or from 1875 to 1892, inclusive, and that during the next three cycles there was a decided increase, the fifth cycle showing a slight increase over the first cycle. From this period until 1908 to 1922 the increase has been a very nominal one, unless we choose to regard the 1918 to 1922 performance as indicating a permanent improvement in the per acre production of potatoes. From the data presented it is evident that the slight gain in average yield per acre (4.4 per cent) in the last of the eleven 5-year cycles over that of the first cycle is not sufficient to account for the increased production of potatoes in the United States. The total average bushel production in the United States for the years 1868 to 1872 was 117,745,800, while in the last 5-year period (1918–1922) the average production was 390,615,600 bushels, or an increase over the first period of more than 231 per cent. During this same period the increase in acreage devoted to potato production has been more than 217 per cent. These data show conclusively that increased production in the United States during the last 55 years has been almost entirely due to increased acreage rather than to any material improvement in cultural practices resulting in larger yields per acre.

Table 1 and the accompanying diagrams (figs. 1 to 3) show the average acre yields, the farm price per bushel, the acreage grown,

[1] The statistical data upon which these studies are based were obtained for the years 1868 to 1888 from the United States Department of Agriculture Yearbook for 1917, p. 657; for 1889 to 1895 from the 1920 Yearbook, p. 617; for 1896 to 1920 from the 1921 Yearbook, p. 583; and for 1921 to 1922 from the December 23, 1922, issue of the United States Department of Agriculture Weather Crops and Markets publication, p. 565.

and the total production of potatoes, while Figure 4 shows the population of the United States during the eleven 5-year cycles studied. In the construction of these diagrams it has not been feasible to employ the same scale in any two of them, owing to the great difference in the magnitude of the figures treated. A careful study of the first diagram (fig. 1), in which the acreage yield and

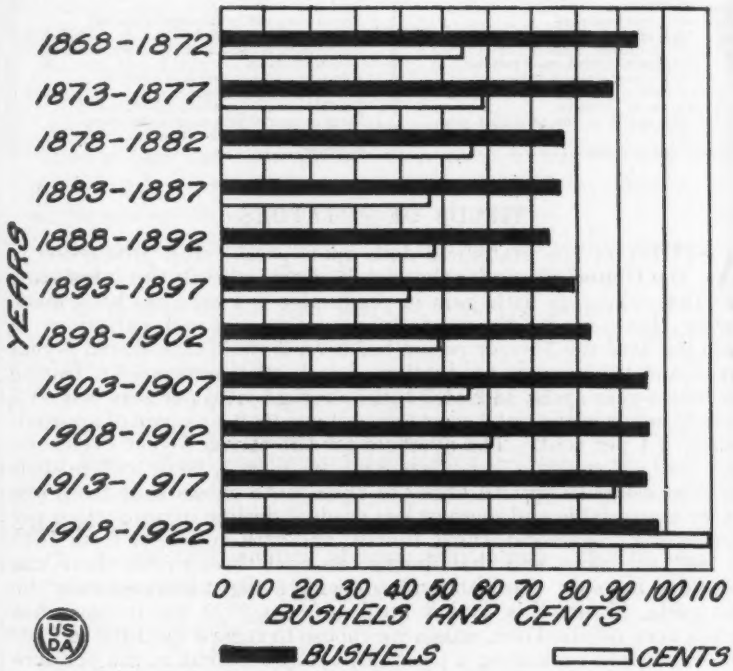

FIG. 1.—Diagram showing the average number of bushels per acre and the average farm price per bushel of potatoes grown in the United States by 5-year periods from 1868 to 1922.

farm price per bushel are given, shows that the acreage-production curve, if drawn on the chart, would somewhat resemble the curve of a scimitar blade, in which the extreme ends of the blade represent the maximum yields for each half of the curve.

TABLE 1.—*Averages of acreage, production, and farm values of potatoes in 5-year periods from 1868 to 1922, inclusive.*

5-year period.	Number of acres.	Production (bushels).		Farm value on Dec. 1.	
		Total	Per acre.	Total.	Per bushel (cents).
1868 to 1872	1,246,200	117,745,800	94.5	$64,123,600	54.5
1873 to 1877	1,529,800	134,773,200	88.1	68,665,600	50.9
1878 to 1882	1,934,200	150,706,200	77.9	85,547,200	56.8
1883 to 1887	2,284,000	175,197,800	76.7	82,295,000	46.9
1888 to 1892	2,633,800	194,939,400	74.0	93,012,600	47.7
1893 to 1897	2,900,400	231,757,800	79.9	95,258,400	41.1
1898 to 1902	2,968,200	243,866,400	82.2	117,671,600	48.3
1903 to 1907	3,213,200	309,568,200	96.3	170,652,800	55.1
1908 to 1912	3,644,400	351,793,800	96.5	213,038,200	60.6
1913 to 1917	3,812,400	366,045,600	96.0	322,292,400	88.0
1918 to 1922	3,948,400	390,615,600	98.9	425,975,400	109.1

The gradual decline in yields during the first half of this period is thought to be largely due to the following factors:

The ravages occasioned by the Colorado potato beetle during the early period of its invasion of the eastern United States.

The financial depressions of 1877 and 1893, which brought about a well-marked decline in agriculture in New England, New York, and the other heavy potato-producing areas of the northeastern United States.

A gradual depletion of soil fertility.

Of the factors which have checked the downward tendency and contributed most largely toward a return to the old production level the following are thought to have been most potent:

The influence of the agricultural experiment stations, agricultural colleges, and the United States Department of Agriculture through experimentations, demonstration, and the dissemination of literature.

The influence of the Bordeaux-mixture treatment in the control of fungous diseases affecting the potato.

The development of special potato-growing sections, as, for example, Aroostook County, Me., the Atlantic Coastal Plain trucking region, the Greeley and Carbondale districts of Colorado, and many other areas, in which the average yield is approximately from two to three times the general average for the United States.

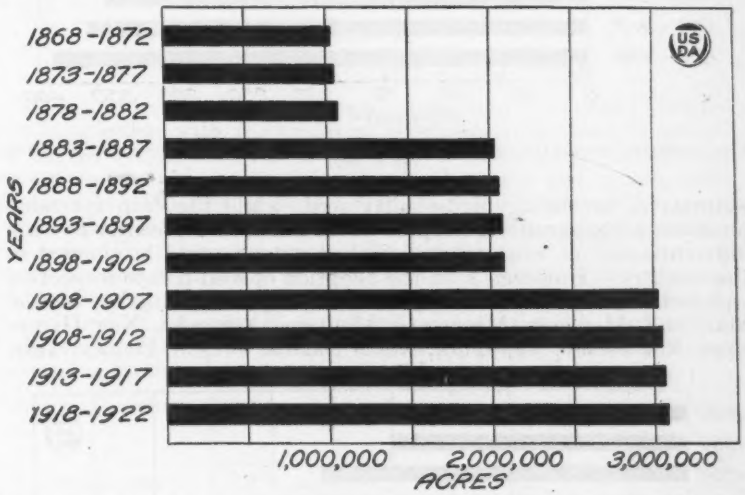

FIG. 2.—Diagram showing the average potato acreage of the United States by 5-year periods from 1868 to 1922.

Figures 1 to 4 show a comparison of the relation of increased production to a constantly increasing population. The diagrams show that under normal conditions production is keeping pace with population. Crop shortages are, therefore, the result of abnormal or unfavorable conditions.

In comparing the average crop production of potatoes in the United States with that of Great Britian, one is impressed with the fact that generally speaking we have much yet to learn before we can raise our average to that of that country. During the years 1901 to 1910, inclusive, the average acre yield in Great Britain was approximately 200 bushels, while that in the United States was not quite 93 bushels.

Of the many causes which produce a low average potato yield in this country, poor seed is thought to be important. The American potato grower pays too little attention to his seed potatoes. European growers pay very strict attention to the quality and quantity of seed they use. This has led to the differentiation of the potato growers into seed and crop specialists. The seed specialist makes a

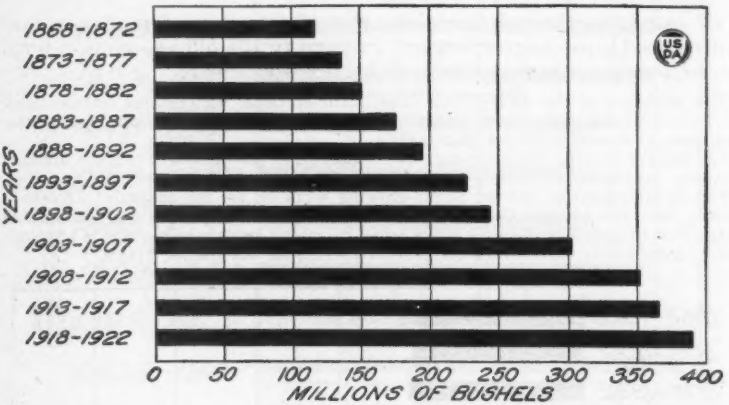

FIG. 3.—Diagram showing the average potato production of the United States by 5-year periods from 1868 to 1922.

business of producing high-quality seed, while the crop specialist produces a high-grade table potato. Until rather recently no such differentiation, at least to any marked extent, could be claimed in this country. However, with the adoption of seed-potato inspection and certification in California, Colorado, Idaho, Kentucky, Maine, Maryland, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Oregon, Pennsylvania,

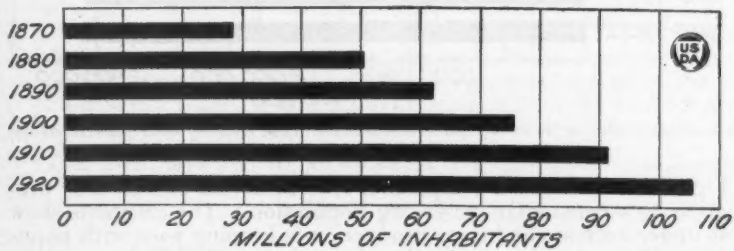

FIG. 4.—Diagram showing the population of the United States by decades from 1870 to 1920.

South Dakota, Vermont, Washington, Wisconsin, Wyoming, and all of the Canadian Provinces, groups of seed-potato growers are gradually being evolved. A further stimulus to those who are engaged in the production of seed potatoes is the increasing demand for good seed stock at prices which are sufficiently remunerative to well repay the grower for the extra care given to the crop.

WHAT CONSTITUTES GOOD SEED.

Two factors are involved in the consideration of good seed potatoes: (1) The physical or outward appearance of the tubers and (2) the heritable or transmissible characters of the stock. The first involves the purity and maturity of the stock, uniformity in size and shape of the tubers, brightness of skin, firmness of flesh with first sprouts just showing, and freedom from scab, Rhizoctonia, late-blight, or other tuber-decay diseases. The second factor deals with nonobservable characters and is by far the more important one, as it involves the presence or absence of the virus diseases causing mosaic, leaf-roll, spindle-tuber, streak, and yellow dwarf. Freedom from the virus diseases is an important consideration and can only be assured through personal inspection of the growing plants from which the seed was obtained or by the purchase of reliably certified stock. If in any given year it were possible to plant the entire potato acreage of the United States with first-class seed stock the total production would be increased from 10 to 25 per cent. Based on the average production for the 5-year period from 1918 to 1922, this increase would represent from 39 to 97½ million bushels, or an increase in money value of $40,333,000 to $106,333,000.

CERTIFIED AND UNCERTIFIED SEED.

The rapid increase in acreage and production of certified seed potatoes, together with the premium over uncertified seed demanded by the grower for such stock, has made it necessary to demonstrate its superiority over ordinary seed. In the early and consequently developmental period of seed certification the producers' claims of superiority were not sufficiently well supported by experimental evidence to make them convincing. To-day there is abundant evidence of the general superiority of certified over uncertified seed potatoes. In a recent paper presented at the 1924 annual meeting of the Potato Association of America, H. C. Moore, of the Michigan Agricultural College, submitted data covering actual comparative tests by a large number of independent investigators, as shown in Table 2.[2]

TABLE 2.—*Comparative tests of potato yields, showing the advantage of using certified seed.*

Location of tests.	Number of tests or reports.	Average increase in yields per acre (bushels).	Location of tests.	Number of tests or reports.	Average increase in yields per acre (bushels).
Canada (8 Provinces)	15	88	Michigan	314	73
Connecticut	144	53	Missouri	46	43
Delaware	21	83	Montana	2	219
Indiana	9,740	44	Nebraska	64	141
Illinois	15	47	New York	68	76
Kansas	11	41	Ohio	168	48
Kentucky	220	42	Oregon	3	150
Louisiana	31	42	Pennsylvania	87	41
Maine	279	83	South Carolina	8	31
Massachusetts		75			

These and many other data serve to emphasize the value of high-grade seed. They also indicate the general superiority of certified over noncertified stocks as a source of good seed.

[2] Moore, H. C. Evidence that certified seed is improved seed. *In* Proc. 11th Ann. Meeting, Potato Assoc. America, 1924, p. 28. 1925.

UNIFORMITY IN SIZE AND SHAPE OF TUBERS.

Under normal conditions of growth many present-day commercial varieties are very variable in size and shape of tuber. To some extent both size and shape are determined by the character of the soil, rate of planting, fertilization, and cultural care given the growing crop. Inheritance, however, plays a very important part. Most varieties contain within themselves distinct varietal strains which when isolated are much more uniform in respect to size and shape than the variety itself. Other things being equal, the variety or varietal strain that produces the greatest number of fair-sized shapely tubers and the smallest number of ill-shaped and small tubers should prove the most valuable, because it involves less waste to both the grower and the consumer. It is particularly important at present that such strains be developed, because there is an increasing demand for fancy table stock to satisfy the requirements of a large and discriminating class of consumers who are insisting on greater uniformity in size and shape and are willing to pay a premium on such grades.

DEVELOPMENT OF HIGH-GRADE SEED POTATOES.

The successful production of high-grade seed potatoes is very largely dependent upon the following factors: (*1*) *Starting with a good strain;* (*2*) *the proper treatment of the seed;* (*3*) *thorough preparation and proper fertilization of the soil;* (*4*) *the following of the best cultural practices, including protection against insect and fungous pests;* (*5*) *the elimination of all mixtures and all diseased or weak plants; and* (*6*) *the careful harvesting and proper storage of the crop.*

SECURING A GOOD STRAIN OF SEED.

If the strain of seed you are using is lacking in vigor, it is generally advisable to discard it and purchase a new lot from some reliable grower whose stock you have reason to believe is superior to yours. This suggestion is made as the result of a rather wide experience in trying to improve poor strains of potatoes through selection methods. Such attempts have usually resulted in failure, and it is felt that as a rule much more satisfactory progress can be made by starting with a new strain. Further improvement can usually be secured through selection.

SEED-POTATO IMPROVEMENT BY SELECTION.

The improvement of seed potatoes by selective processes has long engaged the attention of the potato grower. Recent experimental evidence seems to indicate that the possibilities of improving potato seed stock by selective processes alone are not as great as many writers upon this subject have claimed. To those who have devoted much time and effort to the improvement of the potato by selection it would appear that the chances of finding superior yielding true-to-type strains within a variety are not as great as has been believed. The chief advantages to be derived from seed-potato selection practices are the elimination of diseased and weak plants and the removal of varietal mixtures.

IMPROVEMENT PRACTICES.

Five improvement practices may be used in securing a high-yielding and commercially desirable strain of potatoes: (1) The tuber-unit method, (2) hill selection, (3) mass selection, (4) field roguing, and (5) strain testing.

In early editions of Farmers' Bulletin 533 considerable emphasis was laid upon the tuber-unit method of seed-potato improvement; subsequent experiences of the writer and others have indicated that this method is not as satisfactory or as practical in operation as the other four methods suggested. It is thought desirable, however, to briefly describe the tuber-unit method because some of its processes are applicable to other selection methods.

TUBER-UNIT METHOD.[1]

The tuber-unit method, as now generally understood, consists in selecting from the seed bin before planting time a considerable number of the most perfectly shaped tubers ranging from 6 to 8 ounces in weight. When planted, these tubers are quartered, as dropped, into four as nearly equal parts as possible, by splitting the bud-eye cluster twice from seed to stem end of the tuber. In other words, the tuber is cut through its longitudinal axis. The four pieces of each tuber are dropped consecutively in the row at a distance of from 10 to 12 inches apart in the furrow. All tubers showing discoloration of the flesh or other evidence of disease should be rejected. By allowing an additional spacing between each set of fours, the four plants from each tuber are definitely isolated from adjoining ones and the grower can readily observe any variation in vigor and uniformity between the various units planted. This method also enables him to detect any mixtures that may occur in the variety. All mixtures should at once be removed. By marking the units which appear to be the most uniform in size, vigor, and type when the plants are still in vigorous growth, the first step in selection has been accomplished. At digging time the product of each unit is separately harvested and a further selection made from the marked units of all tubers which most nearly approach the size, shape, and smoothness desired. The selected tubers of each unit should be separately placed in small sacks, preferably cotton or burlap, numbered with both field and unit numbers, and stored to await further examination. The final examination should produce data on the number and weight of merchantable and unmerchantable tubers and their general conformity in size, shape, and smoothness of the type desired. From each of the units retained 10 of the best tubers should be selected for the next season's planting.

It is desirable to maintain the study of each selection on the tuber-unit basis the following season, because it permits a more accurate comparison of the behavior of each. The 10 selected tubers from each original unit will give 40 plants for study the second year. All selections which do not produce a reasonably uniform lot of plants should be marked for rejection. At harvest time the progeny of each selec-

[1] For further information concerning the arrangement of a tuber-unit selection plat and a convenient system of note taking, see Stuart, William, The "tuber-unit" method of seed-potato improvement. U. S. Dept. Agr., Bur. Plant Indus. Cir. 113, pp. 25-31, 2 fig. 1913.

tion should be kept by itself and the same data recorded as those taken on the crop grown from the original tuber unit. Only the product from such 40-hill rows as meet the most rigid requirements should be retained. The further conduct of the work will consist in the multiplication of the selected strains for field planting and the elimination of weak plants.

HILL SELECTION.

The hill-selection method consists in marking the most promising plants during the growing season and at harvesting time saving only those which give the greatest promise. (Figs. 5 and 6.) The progeny of each hill should be kept separate and the same data taken as outlined for the tuber unit. Plant on the tuber-unit or progeny-

FIG. 5.—Progeny of a mosaic-infected potato plant of the Triumph variety on the left (*A*) and of a healthy plant on the right (*B*). Bin selection of such seed would result in taking at least two tubers from the mosaic plant. If small tubers were used all would come from diseased plants. In hill-selection work the progeny of plant B should be saved.

row basis the following season. For the sake of uniformity a definite number of tubers (five or more) should be planted from each hill selection. From this point on, follow the methods given in tuber-unit work.

MASS SELECTION.

Mass selection differs from hill selection in only one respect, which is that the tubers from the individually selected plants are not kept separate. Generally those who practice mass selection do not go to the trouble of marking promising individual plants during the growing season, but simply go through the field before harvesting the whole crop and dig by hand as many plants as may be desired to secure the necessary quantity of seed that show the desired vigor and stem characters thought to be correlated with productiveness, trueness to type, and uniformity in size of tubers of the particular variety grown.

FIELD ROGUING.

Improvement of the seed stock through field roguing consists in the removal of all diseased, weak, off-type, or varietal-mixture plants during the growing season. The successful removal of such plants does not necessarily involve an intimate knowledge of the various diseases affecting the potato, but it does require that the person doing the roguing be able to tell whether a plant is normal or abnormal in appearance. A sufficient field area should be rogued the first year to provide the quantity of seed necessary to plant the full acreage to be grown the ensuing season. The area to be rogued should be gone over at least three times during the growing season, to insure the removal of all plants affected with transferable diseases, such as mosaic and leaf-roll, as soon as their presence can be detected. In the field-roguing method no attempt is made to select the progeny of individual plants at harvesting time, the whole crop being dug and all desirable seed stock gathered and stored in bulk.

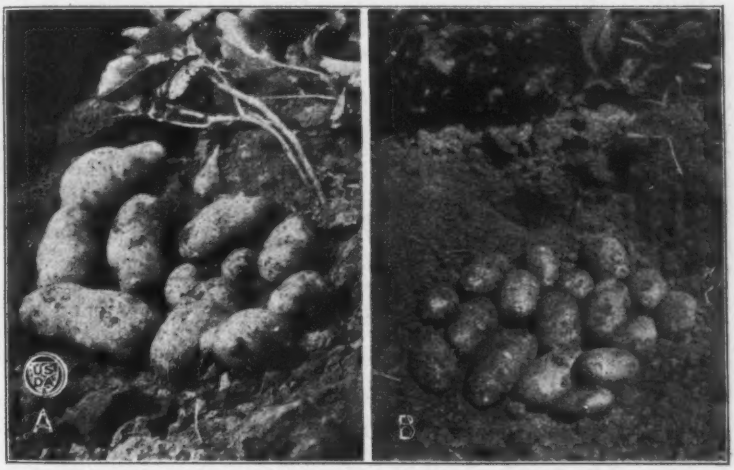

FIG. 6.—Progeny from abnormal (*A*) and normal (*B*) plants of the Russet Burbank potato. Plant A is known in the West as a degenerate or run-out plant, and the disease with which it is affected is probably identical with that recently termed "spindle tuber." It is a communicable disease and may become serious. In hill-selection work the progeny of plants such as *B* should be saved.

STRAIN TESTING.

The improvement of seed potatoes by the strain test, or, as it might more properly be termed, the "source-of-seed test" method, consists in securing as many as possible desirable lots of seed stock of the same variety from different growers throughout a given district or State, or even from various States, and carefully studying their behavior when grown side by side under identical soil and cultural conditions. Experimental studies by this method of seed improvement have demonstrated that some lots or strains of seed stock are far superior to others; in fact, differences in yield of more than 100 bushels per acre have been noted between the lowest and highest yielding strains. Furthermore, it has been conclusively demonstrated by numerous trials that these yields were not accidental, but that in practically every instance the high-yielding strains have consistently given larger yields wherever tested.

The improvement of seed stock by this method does not consist in the actual isolation and development of a strain from a given variety, but rather in locating, as it were, by comparative tests the really superior sources of seed stock. The actual improvement accomplished is measured by the success attending one's efforts in getting live, up-to-date growers to discard their inferior strains and purchase the superior one, as shown by the tests made.

The practical operation of such a movement may be best emphasized by stating that in 1921 over 100 potato growers in Wisconsin grew seed stock of a superior strain of Triumph potatoes located in this manner in 1918.

It should be remembered that whatever selection practice is pursued the fields devoted to the production of high-quality seed must be carefully rogued if the vigor of the seed stock is to be maintained.

RELATIVE MERITS OF THE PRECEDING PRACTICES.

In the preliminary discussion of seed-potato improvement in this bulletin it is intimated that the chance of securing a superior strain of a commercial variety of potato through selective processes is not as great as earlier writers on this subject have claimed. A careful consideration of all the experimental evidence thus far presented would seem to justify the conclusion that the tuber-unit method of seed-potato improvement does not afford as satisfactory a starting point for selection work as the hill-selection method. The evidence at hand would also seem to indicate that neither of these practices is to be commended to the average grower of seed potatoes, as both methods involve an expenditure of a greater amount of time and effort in properly observing the details necessary to their successful application than can reasonably be expected of such a grower. The tuber-unit and hill-selection methods can only be recommended to those growers who have ample time or means to undertake these studies and to those experiment-station investigators who have the facilities necessary for carrying on such work.

The "mass-selection" and the "field-roguing" methods are more nearly adapted to the average grower, as neither method involves the growing and keeping separate of a large number of individual selections. Both are so simple of execution that any person of ordinary intelligence can practice them.

Strain testing involves a somewhat more elaborate plan of operation, in that it requires the purchasing and growing of several strains of a given variety under as nearly identical conditions as it is possible to supply. This method of seed-potato improvement may be best undertaken by the type of men suggested for the conduct of the tuber-unit and hill-selection systems. The average grower should avail himself of the findings of those engaging in strain testing and purchase his seed from those growers having the most desirable seed stock, as demonstrated by such tests.

REQUIREMENTS FOR SUCCESS.

The only requirements for the successful practice of the first two methods of seed selection are a reasonable degree of painstaking effort on the part of the grower, some 12-inch garden labels, a small pair of balances, a sufficient number of suitable small sacks, and a

safe place in which to store the selected tubers until required for the next season's planting. In addition to this, the grower should have a breeding plat in which each season's selections can be developed up to the point of field-planting stock. This selection or seed plat should be located at as great a distance from the commercial potato field as possible in order to secure the greatest degree of isolation that is feasible. Heretofore the problem of isolation has not received due consideration. This was largely owing to the fact that the seriousness of such diseases as mosaic, leaf-roll, curly-dwarf, streak, and spindle-tuber has only recently come to be recognized. The fact that all of these diseases are readily transmitted from diseased to healthy plants through the instrumentality of plant lice, or aphids, and the further fact that as yet there is no reliable information as to the distance insects may transport these diseases suggest as complete isolation of the seed plat as possible. The latest suggestion in regard to the production of seed potatoes under isolation is that each variety be grown separately, as it has been found that stock of certain varieties supposed to be free from mosaic have served as disease carriers to more susceptible varieties. For example, it is not desirable to grow the Irish Cobbler adjacent to the Green Mountain intended for certification, as the former may carry the mosaic virus without expressing it. The danger from contamination of the healthy Green Mountain strain by the Irish Cobbler is considered sufficiently great by some seed-certification agencies to cause them to refuse to consider stock thus grown as eligible for certification. The ultimate success of the seed plat in so far as the elimination of tuber-borne diseases is concerned rests largely upon the ability of the grower to recognize diseased plants and the promptness with which they are removed from the seed plat and destroyed. Frequent and thorough inspections of the seed plat are necessary to insure the largest possible reduction of diseased plants and to reduce the transmission of disease from diseased to healthy plants.

SEED TREATMENT.

It is impossible to produce high-grade seed potatoes if the seed planted is infected with disease organisms capable of infecting the crop. The disinfection of the seed potatoes is therefore necessary if the best results are to follow. The two diseases for which seed potatoes are ordinarily treated are common scab and black scurf, or Rhizoctonia. The two disinfecting agents recommended for such treatment are formalin and corrosive sublimate (mercuric chloride, or bichloride of mercury). Formalin is a trade name for a 40-per-cent solution of formaldehyde gas. Corrosive sublimate is a white crystalline poisonous compound which goes into solution very slowly in cold water but is readily dissolved in boiling hot water. In recent years the hot formaldehyde treatment of seed has been found to be much more effective against black scurf (Rhizoctonia) than the cold-solution treatment, and it requires a much shorter period of immersion. The formulas recommended for these two disease disinfectants are as follows:

1. Formalin:
   a. Cold treatment:
   Formalin, 1 pint.
   Water, 30 gallons.
   b. Hot treatment:
   Formalin, 2 pints.
   Water, 30 gallons, heated to 125° F.

2. Corrosive sublimate 4 ounces.
   Water, 30 gallons.

The period of treatment for formula 1, *a*, and for formula 2 is from 1½ to 2 hours when the seed is dormant and one-half to 1½ hours if the tubers are germinated. With formula 1, *b*, on account of the double strength of the solution and the higher temperature of the liquid the period of treatment is cut to 4 or 5 minutes. In using the hot formaldehyde solution it is necessary to have a reliable thermometer and a well-controlled method of maintaining a uniform temperature throughout the treatment.

The treated tubers should on no account be allowed to come in contact with such receptacles as old sacks and barrels in which diseased seed has been handled, as they are almost certain sources of reinfection.

PREPARATION AND FERTILIZATION OF THE SOIL.

Strong, vigorous plants can not be produced on land that has been poorly prepared or that is deficient in available plant food. Seed potatoes should be grown on land that has been deeply plowed and thoroughly prepared to receive the seed. It should be well supplied with organic matter and available plant food. A clover or alfalfa sod furnishes the organic matter and considerable of the plant food. Barnyard manures or commercial fertilizers, or both, will supply the additional plant food necessary to produce a good crop

CAREFUL CULTURAL PRACTICES.

The vigor of the seed stock produced is to a large extent dependent on the care given to the growing crop. Uniformity in the size of the tubers is to a large extent governed by the rate of planting. Closer planting should be practiced in the growing of seed than of table stock. Some growers in Aroostook County, Me., space their rows from 32 to 36 inches apart and the plants in the row 8 to 12 inches. The crop should be cultivated as frequently as may be necessary to provide the most suitable growing conditions.

Every effort should be made to protect the plants from injury by insect or fungous pests. Leaf-eating insects can be effectively controlled if the plants are thoroughly sprayed with arsenical poisons; sucking insects with contact solutions, such as kerosene emulsion and nicotine; and fungous diseases, such as the early and late blights, with Bordeaux mixture. In every operation it should be remembered that whatever contributes to the health of the plant increases the vigor of the seed stock produced.

ELIMINATION OF VARIETAL MIXTURES AND DISEASED OR WEAK PLANTS.

The vegetable-seed growers employ the term "roguing" to denote the process of removing all mixtures or off-type plants from the seed plat. As this term, when understood, is a brief and yet sufficiently descriptive way of indicating the process of eliminating all undesirable plants or "rogues," it is proposed to use it in this connection.

It is an easy matter to rogue a seed-improvement or selection plat during the growing season. Varietal mixtures are more easily detected when the plants are in bloom. Weak plants are usually apparent in the early stages of their growth, as are also certain types of diseases, such as mosaic and black-leg, although both may appear later. Plants infected with Rhizoctonia and Fusarium are usually

not apparent until the latter part of the growing season. It is evident from these statements that in order to rogue the seed plat thoroughly it is necessary to make two or three examinations of the field or plat during the growing season. Further roguing should be done when the crop is harvested by discarding the progeny of all low-producing plants. (Fig. 5, *A*.)

MONETARY VALUE OF GOOD SEED POTATOES.

The producer of high-grade seed potatoes is justly entitled to a fair monetary return for the special efforts he has made to produce quality seed stock. This is especially true where a seed plat is maintained year after year and the crop has been officially inspected and passed by a duly authorized seed-certification inspection officer. Just what increase in price over ordinary stock one is entitled to receive for such efforts and for the inspection fees involved is not an easy matter to determine. It is believed that a premium of 50 cents per bushel over the market price of table stock of the same variety is ordinarily sufficient to amply repay the grower. Opinions, however, will differ upon this point. At the present time the price of certified seed stock varies all the way from $1 to $3.50 per hundredweight—60 cents to $2.10 per bushel.

IMPORTANCE OF TUBER SHAPE.

Reasonable trueness of the tubers to varietal type is generally demanded by the purchaser of certified seed. And most writers who have dealt with the subject of good seed have always placed strong emphasis upon the importance of its being true to type. Rather recently, however, some scientific as well as practical growers have been disposed to regard tuber shape as being of less importance than has been previously supposed. They have come to regard tubers that have departed from the type as a result of unfavorable environmental conditions as being satisfactory for seed purposes.

As a result of a long-continued preachment of the undesirability of slightly off-type tubers for seed purposes many cars of otherwise high-grade seed stock have been annually rejected by the southern truck grower. This is particularly true in the case of conspicuously flattened and somewhat elongated tubers of the Irish Cobbler variety. The Irish Cobbler grower in the South has come to demand roundish tubers and is suspicious of the purity of seed stock containing flattened and somewhat elongated tubers and generally protests their acceptance as strictly first-class seed stock. In fact, he is inclined to regard the off-type tubers as Green Mountain. The only obvious way of correcting these firmly rooted convictions is to demonstrate experimentally that off-type tubers resulting from unfavorable soil, cultural, or climatic conditions are no more likely to produce off-type progeny than are normal-shaped ones. This statement, however, does not apply to off-type tubers resulting from disease; such tubers should not be planted. The spindle-tuber recently recognized by pathologists as a communicable disease is very similar in its method of transmission to that of leaf-roll and the mosaic disease. Figure 6, *A*, represents a fairly good example of spindle tubers. It is important, therefore, in the purchase of somewhat off-type seed potatoes to know whether the change in shape is really due to unfavorable environmental factors and not to disease.

XUM

CAREFUL HARVESTING AND STORAGE OF THE CROP.

The average grower does not fully appreciate the importance of using every means to prevent the mechanical injury of the tubers during the process of harvesting and storing. If the crop is grown on land containing a plenteous admixture of small stones the tubers are almost certain to be more severely injured in harvesting than when grown in a sandy loam soil. Hand digging is not always feasible, but it is believed that where small stones abound in the soil it will be desirable to harvest the home seed plat by hand. Much injury will be avoided if the seed stock designed for planting the field plat of the ensuing year is picked directly into crates in which it is allowed to remain throughout the storage period.

The storage conditions necessary to insure vigorous seed at planting time are more easily provided in the North than in the South. In the former region a well-constructed cellar, pit, or cave serves reasonably well. The main thing is to keep the room temperature sufficiently low to retard germination. The ideal seed tuber is one which has not wasted any of its stored-up energy by excessive loss through sprouting. (Fig. 7.) It should be firm, with the first sprouts just showing. Such tubers can be depended upon, if suitable conditions prevail, to start quickly when planted and to make a vigorous growth.

The general practice among southern growers of securing seed from the North involves in the absence of suitable storage conditions one of two things: Either getting the seed potatoes late in the fall and holding them over in dugouts, pits, or cellars, with consequent sprouting before planting, or the risk of having the seed chilled, frozen, or overheated while in transit in midwinter. In the writer's opinion the greatest need of the large southern truck grower at present is that of suitable storage facilities for handling fall shipments of seed potatoes. As a purely economic proposition the proposed change ought to commend itself. In probably nine cases out of ten the difference in first cost of these potatoes as between fall and midwinter shipments would more than offset the extra cost of storage, while the added security from danger of chilling or freezing the shipment would still further compensate the grower.

For further particulars on storage, consult Farmers' Bulletin 847, entitled "Potato Storage and Storage Houses."

LARGE COMPARED WITH SMALL SEED TUBERS.

In seasons of short production and consequent high prices for table stock, the question is frequently raised as to the advisability of using the small unsalable tubers for seed. The answer to this question is that it is always unsafe to use small tubers for seed purposes unless one is absolutely certain that they have been produced by healthy, vigorous, and productive plants. As a result of some experimental study of this question by Ballou and Gourley[4] it was found that the use of large tubers gave—

(*a*) A very heavy, perhaps almost total, percentage of the high-producing strains.
(*b*) A heavy percentage of the average or moderate-yielding strains.
(*c*) A very small percentage of the inferior or low-producing strains.

[4] Ballou, F. H., and Gourley, J. H. I. The status of the potato growing industry in Ohio. II. Seasonal notes on potatoes. Ohio Agr. Exp. Sta. Bul. 218, p. 587. 1910.

The use of small potatoes gives—

(*a*) A very insignificant percentage of the superior or high-yielding strains.
(*b*) A small percentage of the average or moderate-yielding strains.
(*c*) A very heavy, almost total, percentage of the low-yielding or inferior strains.

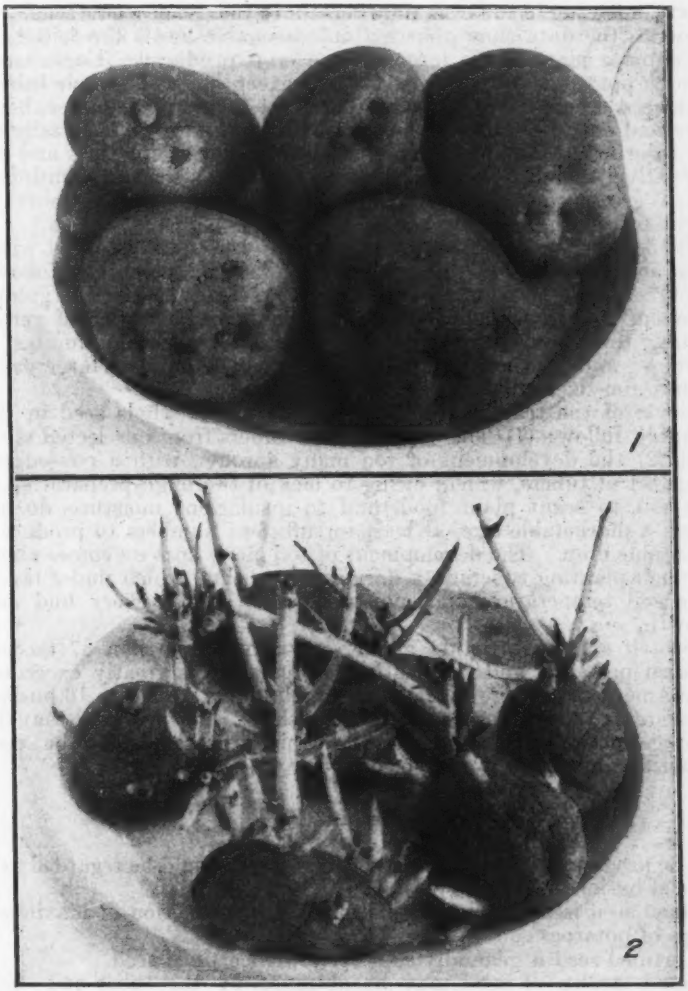

FIG. 7.—Potatoes for seed purposes, showing different stages of germination: 1, Desirable; 2, undesirable.

The use of small seed potatoes is only permissible when they are known to have been produced by strong, healthy, and productive plants. It is never advisable to use small tubers from the general mass produced from unselected stock.

WHOLE COMPARED WITH CUT SEED.[5]

Considerable attention has been paid to the subject of whole versus cut seed at various times by the State agricultural experiment stations. The data accumulated in these investigations are for the most part conflicting in so far as they pertain to the use of whole seed. In general, the data show that within reasonable limits the larger the seed piece planted the larger is the crop produced. English and Scotch potato growers almost without exception plant whole tubers. The seed used usually runs from 1¼ to 2¼ inches in diameter, being screened out of a crop which as a rule has been grown especially for seed purposes. They are harvested before they are mature, and but a relatively small proportion of the crop exceeds the size mentioned. These growers believe that an earlier and more vigorous growth is secured from immature tubers.

Some of the reasons why European growers have adopted whole seed and are succeeding in producing profitable crops are as follows: (1) They are assured of an almost perfect stand; (2) there is greater freedom from disease; (3) the almost universal practice of germinating their seed before planting insures a minimum number of sprouts; and (4) the greater fertility of their land makes large yields of medium-sized tubers possible.

Some of the reasons for failure in the use of whole seed in this country follow: (1) The use of small tubers from unselected stock and (2) the development of too many sprouts, with a consequent large set of tubers, which, owing to lack of thorough preparation of the soil, to scant plant food, and to insufficient moisture, do not reach a marketable size, at least in sufficient numbers to produce a profitable crop. The development of too many sprouts comes about through planting tubers in a dormant condition, which under favorable soil temperature and moisture starts almost every bud into growth.

Scotch and Irish potato growers plant not less than 37 bushels of seed per acre, and frequently this quantity is greatly exceeded. The American grower, on the other hand, plants from 7 to 16 bushels per acre, with an average of 9 to 11 bushels. It is believed that the average potato production of the United States would be very materially increased if a larger quantity of seed were used.

SUMMARY.

The production of high-grade seed potatoes should be regarded as a special business.

Good seed is a determining factor in the production of maximum crops of potatoes.

Certified seed is generally superior to noncertified seed.

Good strains of seed may be obtained by the tuber-unit, hill-selection, mass-selection, field-roguing, or strain-test methods through the process of elimination.

Like produces like. If tubers from unproductive, weak, or diseased plants are planted, a poor harvest will be reaped. Use seed from productive plants.

[5] Stuart, W., and others. Size of potato sets: Comparisons of whole and cut seed. U. S. Dept. Agr. Bul. 1248, 43 pp., illus. 1924.

Purity of seed stock is an essential quality of good seed. Serious losses are sustained by the grower through mixtures.

Good seed can not be produced unless the growing plants are well cared for and the strain of seed planted was a good one.

A more liberal use of good seed would materially increase the average production per acre.

All seed should be disinfected before planting.

Experimental evidence does not indicate that whole seed is superior to cut seed, at least so far as it relates to the United States.

Good storage facilities are essential to insure sound, firm seed at planting time.

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October 14, 1926

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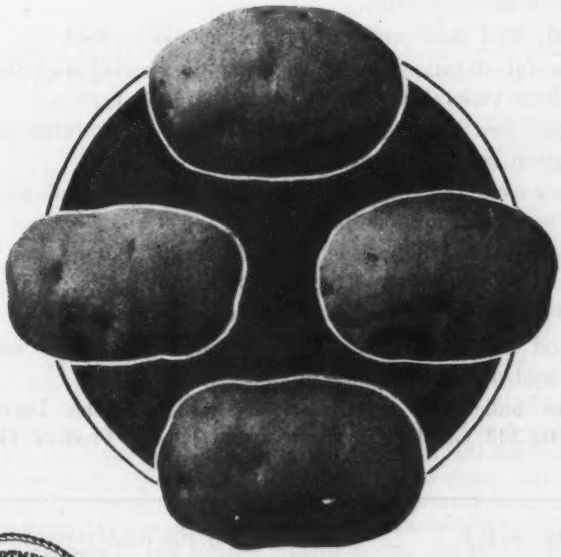
FARMERS' BULLETIN No. 1332 rev.
Nov. 1927

Rev.ed. follows

SEED POTATOES AND HOW TO PRODUCE THEM



XUM

THE AVERAGE PRODUCTION per acre of potatoes in the United States is very much lower than in Canada, Great Britain, and European countries outside of Italy.

One of the reasons for the lower production in the United States is that less attention has been given to the character of the seed. Good seed is one of the determining factors in the production of maximum crops of potatoes.

The use of high-grade seed would increase the returns from the potato crop of the country by many millions of dollars.

The quality of the seed may be improved through the removal of all diseased, weak, or off-type plants as soon as they are observable.

Only seed from productive plants should be used.

Careful attention should be given to securing seed that is free from varietal mixture and that is true to type.

Good seed can not be produced unless the growing plants are given good cultural attention.

As a rule the quantity of seed used is not sufficient to produce a maximum crop.

From 15 to 18 bushels of seed should be used per acre instead of 9 to 11, as at the present time.

All seed stock should be disinfected before planting.

Good storage conditions are essential to insure sound, firm seed at planting time.

This bulletin is a revision of and supersedes Farmers' Bulletin 533, Good Seed Potatoes and How to Produce Them.

Washington, D. C. Issued May, 1923; revised November, 1927

SEED POTATOES AND HOW TO PRODUCE THEM.

By WILLIAM STUART, *Horticulturist, Office of Horticulture, Bureau of Plant Industry.*

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YIELDS OF POTATOES.

A STUDY of the statistical data upon potato crop production in the United States for the last 55 years[1] reveals the interesting fact that relatively little gain in production per acre has been made during this period. To partially minimize seasonal variations in yield per acre the 55-year period has been divided into eleven 5-year cycles and the average production of each cycle compared. During the first 5-year cycle, 1868–1872, the average yield per acre was 94.5 bushels, while in the last 5-year period it was 98.9, or a gain of approximately 4.4 per cent. The averages for the eleven 5-year cycles are 94.5, 88.1, 77.9, 76.7, 74.0, 79.9, 82.2, 96.3, 96.5, 96.0, 98.9 bushels per acre, respectively. A study of these data shows that there was a very appreciable and more or less gradual decline in production per acre during the second, third, fourth, and fifth cycles, or from 1875 to 1892, inclusive, and that during the next three cycles there was a decided increase, the fifth cycle showing a slight increase over the first cycle. From this period until 1908 to 1922 the increase has been a very nominal one, unless we choose to regard the 1918 to 1922 performance as indicating a permanent improvement in the per acre production of potatoes. From the data presented it is evident that the slight gain in average yield per acre (4.4 per cent) in the last of the eleven 5-year cycles over that of the first cycle is not sufficient to account for the increased production of potatoes in the United States. The total average bushel production in the United States for the years 1868 to 1872 was 117,745,800, while in the last 5-year period (1918–1922) the average production was 390,615,600 bushels, or an increase over the first period of more than 231 per cent. During this same period the increase in acreage devoted to potato production has been more than 217 per cent. These data show conclusively that increased production in the United States during the last 55 years has been almost entirely due to increased acreage rather than to any material improvement in cultural practices resulting in larger yields per acre.

Table 1 and the accompanying diagrams (figs. 1 to 3) show the average acre yields, the farm price per bushel, the acreage grown,

[1] The statistical data upon which these studies are based were obtained for the years 1868 to 1888 from the United States Department of Agriculture Yearbook for 1917, p. 657; for 1889 to 1895 from the 1920 Yearbook, p. 617; for 1896 to 1920 from the 1921 Yearbook, p. 583; and for 1921 to 1922 from the December 23, 1922, issue of the United States Department of Agriculture Weather Crops and Markets publication, p. 565.

and the total production of potatoes, while Figure 4 shows the population of the United States during the eleven 5-year cycles studied. In the construction of these diagrams it has not been feasible to employ the same scale in any two of them, owing to the great difference in the magnitude of the figures treated. A careful study of the first diagram (fig. 1), in which the acreage yield and

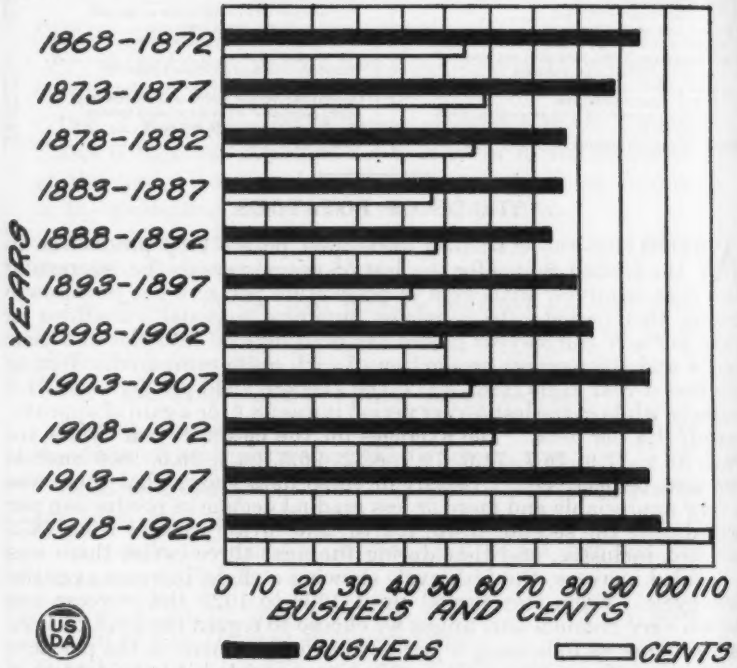

FIG. 1.—Diagram showing the average number of bushels per acre and the average farm price per bushel of potatoes grown in the United States by 5-year periods from 1868 to 1922.

farm price per bushel are given, shows that the acreage-production curve, if drawn on the chart, would somewhat resemble the curve of a scimitar blade, in which the extreme ends of the blade represent the maximum yields for each half of the curve.

TABLE 1.—*Averages of acreage, production, and farm values of potatoes in 5-year periods from 1868 to 1922, inclusive.*

5-year period.	Number of acres.	Production (bushels).		Farm value on Dec. 1.	
		Total	Per acre.	Total.	Per bushel (cents).
1868 to 1872	1,246,200	117,745,800	94.5	$64,123,600	54.5
1873 to 1877	1,529,800	134,773,200	88.1	68,665,600	50.9
1878 to 1882	1,934,200	150,706,200	77.9	85,547,200	56.8
1883 to 1887	2,284,000	175,197,800	76.7	82,295,000	46.9
1888 to 1892	2,633,800	194,939,400	74.0	93,012,600	47.7
1893 to 1897	2,900,400	231,757,800	79.9	95,258,400	41.1
1898 to 1902	2,968,200	243,866,400	82.2	117,671,600	48.3
1903 to 1907	3,213,200	309,568,200	96.3	170,652,800	55.1
1908 to 1912	3,644,400	351,793,800	96.5	213,038,200	60.6
1913 to 1917	3,812,400	366,045,600	96.0	322,292,400	88.0
1918 to 1922	3,948,400	390,615,600	98.9	425,975,400	109.1

The gradual decline in yields during the first half of this period is thought to be largely due to the following factors:

The ravages occasioned by the Colorado potato beetle during the early period of its invasion of the eastern United States.

The financial depressions of 1877 and 1893, which brought about a well-marked decline in agriculture in New England, New York, and the other heavy potato-producing areas of the northeastern United States.

A gradual depletion of soil fertility.

Of the factors which have checked the downward tendency and contributed most largely toward a return to the old production level the following are thought to have been most potent:

The influence of the agricultural experiment stations, agricultural colleges, and the United States Department of Agriculture through experimentations, demonstration, and the dissemination of literature.

The influence of the Bordeaux-mixture treatment in the control of fungous diseases affecting the potato.

The development of special potato-growing sections, as, for example, Aroostook County, Me., the Atlantic Coastal Plain trucking region, the Greeley and Carbondale districts of Colorado, and many other areas, in which the average yield is approximately from two to three times the general average for the United States.

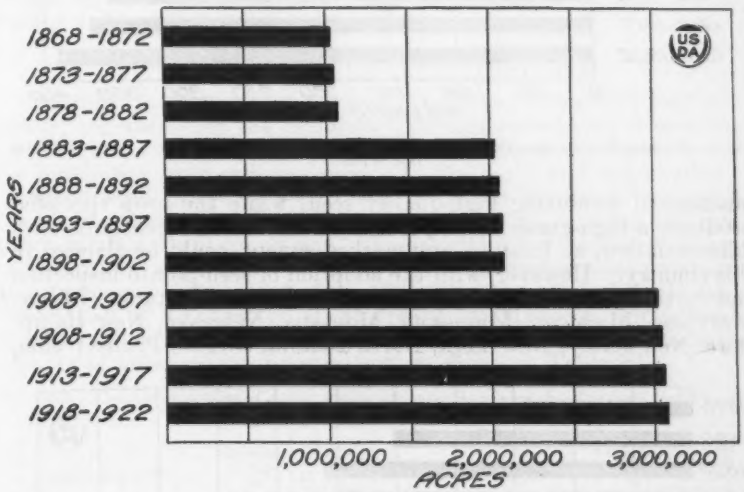

FIG. 2.—Diagram showing the average potato acreage of the United States by 5-year periods from 1868 to 1922.

Figures 1 to 4 show a comparison of the relation of increased production to a constantly increasing population. The diagrams show that under normal conditions production is keeping pace with population. Crop shortages are, therefore, the result of abnormal or unfavorable conditions.

In comparing the average crop production of potatoes in the United States with that of Great Britian, one is impressed with the fact that generally speaking we have much yet to learn before we can raise our average to that of that country. During the years 1901 to 1910, inclusive, the average acre yield in Great Britain was approximately 200 bushels, while that in the United States was not quite 93 bushels.

Of the many causes which produce a low average potato yield in this country, poor seed is thought to be important. The American potato grower pays too little attention to his seed potatoes. European growers pay very strict attention to the quality and quantity of seed they use. This has led to the differentiation of the potato growers into seed and crop specialists. The seed specialist makes a

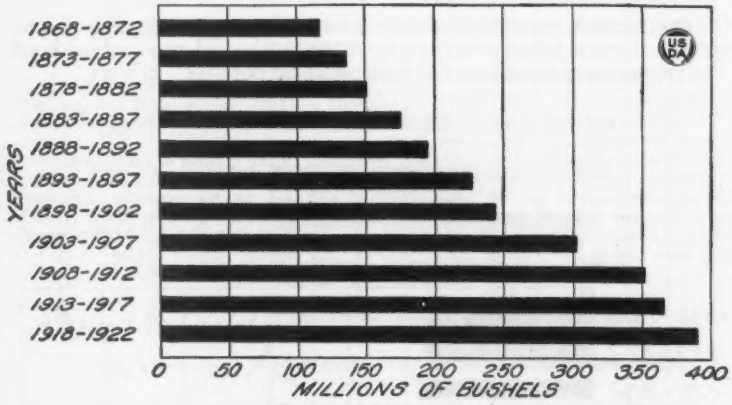

FIG. 3.—Diagram showing the average potato production of the United States by 5-year periods from 1868 to 1922.

business of producing high-quality seed, while the crop specialist produces a high-grade table potato. Until rather recently no such differentiation, at least to any marked extent, could be claimed in this country. However, with the adoption of seed-potato inspection and certification in California, Colorado, Idaho, Kentucky, Maine, Maryland, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Oregon, Pennsylvania,

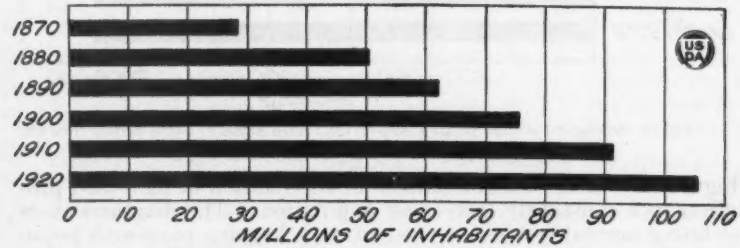

FIG. 4.—Diagram showing the population of the United States by decades from 1870 to 1920.

South Dakota, Vermont, Washington, Wisconsin, Wyoming, and all of the Canadian Provinces, groups of seed-potato growers are gradually being evolved. A further stimulus to those who are engaged in the production of seed potatoes is the increasing demand for good seed stock at prices which are sufficiently remunerative to well repay the grower for the extra care given to the crop.

WHAT CONSTITUTES GOOD SEED.

Two factors are involved in the consideration of good seed potatoes: (1) The physical or outward appearance of the tubers and (2) the heritable or transmissible characters of the stock. The first involves the purity and maturity of the stock, uniformity in size and shape of the tubers, brightness of skin, firmness of flesh with first sprouts just showing, and freedom from scab, Rhizoctonia, late-blight, or other tuber-decay diseases. The second factor deals with nonobservable characters and is by far the more important one, as it involves the presence or absence of the virus diseases causing mosaic, leaf-roll, spindle-tuber, streak, and yellow dwarf. Freedom from the virus diseases is an important consideration and can only be assured through personal inspection of the growing plants from which the seed was obtained or by the purchase of reliably certified stock. If in any given year it were possible to plant the entire potato acreage of the United States with first-class seed stock the total production would be increased from 10 to 25 per cent. Based on the average production for the 5-year period from 1918 to 1922, this increase would represent from 39 to 97½ million bushels, or an increase in money value of $40,333,000 to $106,333,000.

CERTIFIED AND UNCERTIFIED SEED.

The rapid increase in acreage and production of certified seed potatoes, together with the premium over uncertified seed demanded by the grower for such stock, has made it necessary to demonstrate its superiority over ordinary seed. In the early and consequently developmental period of seed certification the producers' claims of superiority were not sufficiently well supported by experimental evidence to make them convincing. To-day there is abundant evidence of the general superiority of certified over uncertified seed potatoes. In a recent paper presented at the 1924 annual meeting of the Potato Association of America, H. C. Moore, of the Michigan Agricultural College, submitted data covering actual comparative tests by a large number of independent investigators, as shown in Table 2.[2]

TABLE 2.—*Comparative tests of potato yields, showing the advantage of using certified seed.*

Location of tests.	Number of tests or reports.	Average increase in yields per acre (bushels).	Location of tests.	Number of tests or reports.	Average increase in yields per acre (bushels).
Canada (8 Provinces)	15	88	Michigan	314	73
Connecticut	144	53	Missouri	46	43
Delaware	21	83	Montana	2	219
Indiana	9,740	44	Nebraska	64	141
Illinois	15	47	New York	68	76
Kansas	11	41	Ohio	168	48
Kentucky	220	42	Oregon	3	150
Louisiana	31	42	Pennsylvania	87	41
Maine	279	83	South Carolina	8	31
Massachusetts		75			

These and many other data serve to emphasize the value of high-grade seed. They also indicate the general superiority of certified over noncertified stocks as a source of good seed.

[2] Moore, H. C. Evidence that certified seed is improved seed. *In* Proc. 11th Ann. Meeting, Potato Assoc. America, 1924, p. 28. 1925.

UNIFORMITY IN SIZE AND SHAPE OF TUBERS.

Under normal conditions of growth many present-day commercial varieties are very variable in size and shape of tuber. To some extent both size and shape are determined by the character of the soil, rate of planting, fertilization, and cultural care given the growing crop. Inheritance, however, plays a very important part. Most varieties contain within themselves distinct varietal strains which when isolated are much more uniform in respect to size and shape than the variety itself. Other things being equal, the variety or varietal strain that produces the greatest number of fair-sized shapely tubers and the smallest number of ill-shaped and small tubers should prove the most valuable, because it involves less waste to both the grower and the consumer. It is particularly important at present that such strains be developed, because there is an increasing demand for fancy table stock to satisfy the requirements of a large and discriminating class of consumers who are insisting on greater uniformity in size and shape and are willing to pay a premium on such grades.

DEVELOPMENT OF HIGH-GRADE SEED POTATOES.

The successful production of high-grade seed potatoes is very largely dependent upon the following factors: (*1*) *Starting with a good strain;* (*2*) *the proper treatment of the seed;* (*3*) *thorough preparation and proper fertilization of the soil;* (*4*) *the following of the best cultural practices, including protection against insect and fungous pests;* (*5*) *the elimination of all mixtures and all diseased or weak plants; and* (*6*) *the careful harvesting and proper storage of the crop.*

SECURING A GOOD STRAIN OF SEED.

If the strain of seed you are using is lacking in vigor, it is generally advisable to discard it and purchase a new lot from some reliable grower whose stock you have reason to believe is superior to yours. This suggestion is made as the result of a rather wide experience in trying to improve poor strains of potatoes through selection methods. Such attempts have usually resulted in failure, and it is felt that as a rule much more satisfactory progress can be made by starting with a new strain. Further improvement can usually be secured through selection.

SEED-POTATO IMPROVEMENT BY SELECTION.

The improvement of seed potatoes by selective processes has long engaged the attention of the potato grower. Recent experimental evidence seems to indicate that the possibilities of improving potato seed stock by selective processes alone are not as great as many writers upon this subject have claimed. To those who have devoted much time and effort to the improvement of the potato by selection it would appear that the chances of finding superior yielding true-to-type strains within a variety are not as great as has been believed. The chief advantages to be derived from seed-potato selection practices are the elimination of diseased and weak plants and the removal of varietal mixtures.

IMPROVEMENT PRACTICES.

Five improvement practices may be used in securing a high-yielding and commercially desirable strain of potatoes: (1) The tuber-unit method, (2) hill selection, (3) tuber index, (4) mass selection, (5) field roguing, and (6) strain testing.

In early editions of Farmers' Bulletin 533 considerable emphasis was laid upon the tuber-unit method of seed-potato improvement; subsequent experiences of the writer and others have indicated that this method is not as satisfactory or as practical in operation as the other four methods suggested. It is thought desirable, however, to briefly describe the tuber-unit method because some of its processes are applicable to other selection methods.

TUBER-UNIT METHOD.[1]

The tuber-unit method, as now generally understood, consists in selecting from the seed bin before planting time a considerable number of the most perfectly shaped tubers ranging from 6 to 8 ounces in weight. When planted, these tubers are quartered, as dropped, into four as nearly equal parts as possible, by splitting the bud-eye cluster twice from seed to stem end of the tuber. In other words, the tuber is cut through its longitudinal axis. The four pieces of each tuber are dropped consecutively in the row at a distance of from 10 to 12 inches apart in the furrow. All tubers showing discoloration of the flesh or other evidence of disease should be rejected. By allowing an additional spacing between each set of fours, the four plants from each tuber are definitely isolated from adjoining ones and the grower can readily observe any variation in vigor and uniformity between the various units planted. This method also enables him to detect any mixtures that may occur in the variety. All mixtures should at once be removed. By marking the units which appear to be the most uniform in size, vigor, and type when the plants are still in vigorous growth, the first step in selection has been accomplished. At digging time the product of each unit is separately harvested and a further selection made from the marked units of all tubers which most nearly approach the size, shape, and smoothness desired. The selected tubers of each unit should be separately placed in small sacks, preferably cotton or burlap, numbered with both field and unit numbers, and stored to await further examination. The final examination should produce data on the number and weight of merchantable and unmerchantable tubers and their general conformity in size, shape, and smoothness of the type desired. From each of the units retained 10 of the best tubers should be selected for the next season's planting.

It is desirable to maintain the study of each selection on the tuber-unit basis the following season, because it permits a more accurate comparison of the behavior of each. The 10 selected tubers from each original unit will give 40 plants for study the second year. All selections which do not produce a reasonably uniform lot of plants should be marked for rejection. At harvest time the progeny of each selec-

[1] For further information concerning the arrangement of a tuber-unit selection plat and a convenient system of note taking, see Stuart, William, The "tuber-unit" method of seed-potato improvement. U. S. Dept. Agr., Bur. Plant Indus. Cir. 113, pp. 25-31, 2 fig. 1913.

tion should be kept by itself and the same data recorded as those taken on the crop grown from the original tuber unit. Only the product from such 40-hill rows as meet the most rigid requirements should be retained. The further conduct of the work will consist in the multiplication of the selected strains for field planting and the elimination of weak plants.

HILL SELECTION.

The hill-selection method consists in marking the most promising plants during the growing season and at harvesting time saving only those which give the greatest promise. (Figs. 5 and 6.) The progeny of each hill should be kept separate and the same data taken as outlined for the tuber unit. Plant on the tuber-unit or progeny-row basis the following season. For the sake of uniformity a definite number of tubers (five or more) should be planted from each hill selection. From this point on, follow the methods given in tuber-unit work.

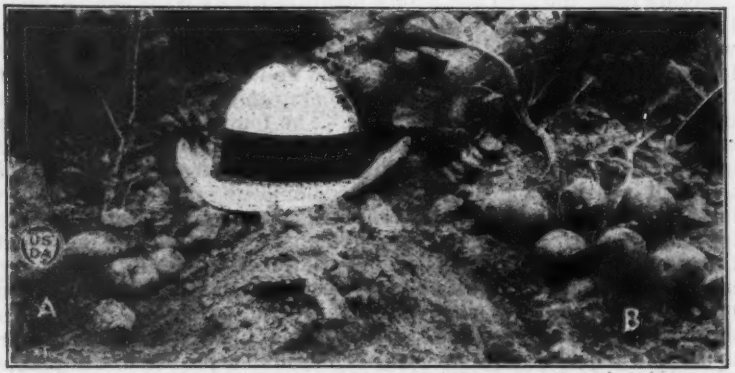

FIG. 5.—Progeny of a mosaic-infected potato plant of the Triumph variety on the left (*A*) and of a healthy plant on the right (*B*). Bin selection of such seed would result in taking at least two tubers from the mosaic plant. If small tubers were used all would come from diseased plants. In hill-selection work the progeny of plant B should be saved.

TUBER INDEX.

In the tuber-index method each tuber is numbered and a seed piece removed which is potted in a 4-inch pot and grown in the greenhouse during the winter season. All seed pieces showing disease are noted and the parent tuber discarded. By this method it is possible to eliminate most if not all of the virus-infected tubers. It is the most effective method known for the elimination of nonobservable diseases in the tuber.

MASS SELECTION.

Mass selection differs from hill selection in only one respect, which is that the tubers from the individually selected plants are not kept separate. Generally those who practice mass selection do not go to the trouble of marking promising individual plants during the growing season, but simply go through the field before harvesting the whole crop and dig by hand as many plants as may be desired to secure the necessary quantity of seed that show the desired vigor and stem characters thought to be correlated with productiveness, trueness to type, and uniformity in size of tubers of the particular variety grown.

FIELD ROGUING.

Improvement of the seed stock through field roguing consists in the removal of all diseased, weak, off-type, or varietal-mixture plants during the growing season. The successful removal of such plants does not necessarily involve an intimate knowledge of the various diseases affecting the potato, but it does require that the person doing the roguing be able to tell whether a plant is normal or abnormal in appearance. A sufficient field area should be rogued the first year to provide the quantity of seed necessary to plant the full acreage to be grown the ensuing season. The area to be rogued should be gone over at least three times during the growing season, to insure the removal of all plants affected with transferable diseases, such as mosaic and leaf-roll, as soon as their presence can be detected. In the field-roguing method no attempt is made to select the progeny of individual plants at harvesting time, the whole crop being dug and all desirable seed stock gathered and stored in bulk.

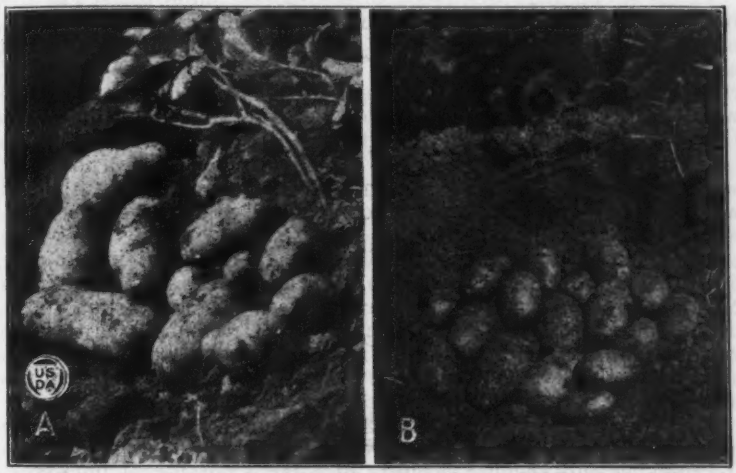

FIG. 6.—Progeny from abnormal (*A*) and normal (*B*) plants of the Russet Burbank potato. Plant A is known in the West as a degenerate or run-out plant, and the disease with which it is affected is probably identical with that recently termed "spindle tuber." It is a communicable disease and may become serious. In hill-selection work the progeny of plants such as *B* should be saved.

STRAIN TESTING.

The improvement of seed potatoes by the strain test, or, as it might more properly be termed, the "source-of-seed test" method, consists in securing as many as possible desirable lots of seed stock of the same variety from different growers throughout a given district or State, or even from various States, and carefully studying their behavior when grown side by side under identical soil and cultural conditions. Experimental studies by this method of seed improvement have demonstrated that some lots or strains of seed stock are far superior to others; in fact, differences in yield of more than 100 bushels per acre have been noted between the lowest and highest yielding strains. Furthermore, it has been conclusively demonstrated by numerous trials that these yields were not accidental, but that in practically every instance the high-yielding strains have consistently given larger yields wherever tested.

The improvement of seed stock by this method does not consist in the actual isolation and development of a strain from a given variety, but rather in locating, as it were, by comparative tests the really superior sources of seed stock. The actual improvement accomplished is measured by the success attending one's efforts in getting live, up-to-date growers to discard their inferior strains and purchase the superior one, as shown by the tests made.

The practical operation of such a movement may be best emphasized by stating that in 1921 over 100 potato growers in Wisconsin grew seed stock of a superior strain of Triumph potatoes located in this manner in 1918.

It should be remembered that whatever selection practice is pursued the fields devoted to the production of high-quality seed must be carefully rogued if the vigor of the seed stock is to be maintained.

RELATIVE MERITS OF THE PRECEDING PRACTICES.

In the preliminary discussion of seed-potato improvement in this bulletin it is intimated that the chance of securing a superior strain of a commercial variety of potato through selective processes is not as great as earlier writers on this subject have claimed. A careful consideration of all the experimental evidence thus far presented would seem to justify the conclusion that the tuber-index method is the most effective and that the tuber-unit method of seed-potato improvement does not afford as satisfactory a starting point for selection work as the hill-selection method. The evidence at hand would also seem to indicate that none of these practices is to be commended to the average grower of seed potatoes, as they involve an expenditure of a greater amount of time and effort in properly observing the details necessary to their successful application than can reasonably be expected of such a grower. The tuber-unit, tuber-index, and hill-selection methods can only be recommended to those growers who have ample time or means to undertake these studies and to those experiment-station investigators who have the facilities necessary for carrying on such work.

The "mass-selection" and the "field-roguing" methods are more nearly adapted to the average grower, as neither method involves the growing and keeping separate of a large number of individual selections. Both are so simple of execution that any person of ordinary intelligence can practice them.

Strain testing involves a somewhat more elaborate plan of operation, in that it requires the purchasing and growing of several strains of a given variety under as nearly identical conditions as it is possible to supply. This method of seed-potato improvement may be best undertaken by the type of men suggested for the conduct of the tuber-unit, tuber-index, and hill-selection systems. The average grower should avail himself of the findings of those engaging in strain testing and purchase his seed from those growers having the most desirable seed stock, as demonstrated by such tests.

REQUIREMENTS FOR SUCCESS.

The only requirements for the successful practice of the first three methods of seed selection are a reasonable degree of painstaking effort on the part of the grower, som 12-inch garden labels, a small pair of balances, a sufficient number of suitable small sacks, and a

safe place in which to store the selected tubers until required for the next season's planting. In addition to this, the grower should have a breeding plat in which each season's selections can be developed up to the point of field-planting stock. This selection or seed plat should be located at as great a distance from the commercial potato field as possible in order to secure the greatest degree of isolation that is feasible. Heretofore the problem of isolation has not received due consideration. This was largely owing to the fact that the seriousness of such diseases as mosaic, leaf-roll, curly-dwarf, streak, and spindle-tuber has only recently come to be recognized. The fact that all of these diseases are readily transmitted from diseased to healthy plants through the instrumentality of plant lice, or aphids, and the further fact that as yet there is no reliable information as to the distance insects may transport these diseases suggest as complete isolation of the seed plat as possible. The latest suggestion in regard to the production of seed potatoes under isolation is that each variety be grown separately, as it has been found that stock of certain varieties supposed to be free from mosaic have served as disease carriers to more susceptible varieties. For example, it is not desirable to grow the Irish Cobbler adjacent to the Green Mountain intended for certification, as the former may carry the mosaic virus without expressing it. The danger from contamination of the healthy Green Mountain strain by the Irish Cobbler is considered sufficiently great by some seed-certification agencies to cause them to refuse to consider stock thus grown as eligible for certification. The ultimate success of the seed plat in so far as the elimination of tuber-borne diseases is concerned rests largely upon the ability of the grower to recognize diseased plants and the promptness with which they are removed from the seed plat and destroyed. Frequent and thorough inspections of the seed plat are necessary to insure the largest possible reduction of diseased plants and to reduce the transmission of disease from diseased to healthy plants.

SEED TREATMENT.

It is impossible to produce high-grade seed potatoes if the seed planted is infected with disease organisms capable of infecting the crop. The disinfection of the seed potatoes is therefore necessary if the best results are to follow. The two diseases for which seed potatoes are ordinarily treated are common scab and black scurf, or Rhizoctonia. The two disinfecting agents recommended for such treatment are formalin and corrosive sublimate (mercuric chloride, or bichloride of mercury). Formalin is a trade name for a 40-per-cent solution of formaldehyde gas. Corrosive sublimate is a white crystalline poisonous compound which goes into solution very slowly in cold water but is readily dissolved in boiling hot water. In recent years the hot formaldehyde treatment of seed has been found to be much more effective against black scurf (Rhizoctonia) than the cold-solution treatment, and it requires a much shorter period of immersion. The formulas recommended for these two disease disinfectants are as follows:

1. Formalin:
   a. Cold treatment:
   Formalin, 1 pint.
   Water, 30 gallons.
   b. Hot treatment:
   Formalin, 2 pints.
   Water, 30 gallons, heated to 125° F.

2. Corrosive sublimate 4 ounces.
   Water, 30 gallons.

The period of treatment for formula 1, *a*, and for formula 2 is from 1½ to 2 hours when the seed is dormant and one-half to 1½ hours if the tubers are germinated. With formula 1, *b*, on account of the double strength of the solution and the higher temperature of the liquid the period of treatment is cut to 4 or 5 minutes. In using the hot formaldehyde solution it is necessary to have a reliable thermometer and a well-controlled method of maintaining a uniform temperature throughout the treatment.

The treated tubers should on no account be allowed to come in contact with such receptacles as old sacks and barrels in which diseased seed has been handled, as they are almost certain sources of reinfection.

PREPARATION AND FERTILIZATION OF THE SOIL.

Strong, vigorous plants can not be produced on land that has been poorly prepared or that is deficient in available plant food. Seed potatoes should be grown on land that has been deeply plowed and thoroughly prepared to receive the seed. It should be well supplied with organic matter and available plant food. A clover or alfalfa sod furnishes the organic matter and considerable of the plant food. Barnyard manures or commercial fertilizers, or both, will supply the additional plant food necessary to produce a good crop

CAREFUL CULTURAL PRACTICES.

The vigor of the seed stock produced is to a large extent dependent on the care given to the growing crop. Uniformity in the size of the tubers is to a large extent governed by the rate of planting. Closer planting should be practiced in the growing of seed than of table stock. Some growers in Aroostook County, Me., space their rows from 32 to 36 inches apart and the plants in the row 8 to 12 inches. The crop should be cultivated as frequently as may be necessary to provide the most suitable growing conditions.

Every effort should be made to protect the plants from injury by insect or fungous pests. Leaf-eating insects can be effectively controlled if the plants are thoroughly sprayed with arsenical poisons; sucking insects with contact solutions, such as kerosene emulsion and nicotine; and fungous diseases, such as the early and late blights, with Bordeaux mixture. In every operation it should be remembered that whatever contributes to the health of the plant increases the vigor of the seed stock produced.

ELIMINATION OF VARIETAL MIXTURES AND DISEASED OR WEAK PLANTS.

The vegetable-seed growers employ the term "roguing" to denote the process of removing all mixtures or off-type plants from the seed plat. As this term, when understood, is a brief and yet sufficiently descriptive way of indicating the process of eliminating all undesirable plants or "rogues," it is proposed to use it in this connection.

It is an easy matter to rogue a seed-improvement or selection plat during the growing seascn. Varietal mixtures are more easily detected when the plants are in bloom. Weak plants are usually apparent in the early stages of their growth, as are also certain types of diseases, such as mosaic and black-leg, although both may appear later. Plants infected with Rhizoctonia and Fusarium are usually

not apparent until the latter part of the growing season. It is evident from these statements that in order to rogue the seed plat thoroughly it is necessary to make two or three examinations of the field or plat during the growing season. Further roguing should be done when the crop is harvested by discarding the progeny of all low-producing plants. (Fig. 5, *A*.)

MONETARY VALUE OF GOOD SEED POTATOES.

The producer of high-grade seed potatoes is justly entitled to a fair monetary return for the special efforts he has made to produce quality seed stock. This is especially true where a seed plat is maintained year after year and the crop has been officially inspected and passed by a duly authorized seed-certification inspection officer. Just what increase in price over ordinary stock one is entitled to receive for such efforts and for the inspection fees involved is not an easy matter to determine. It is believed that a premium of 50 cents per bushel over the market price of table stock of the same variety is ordinarily sufficient to amply repay the grower. Opinions, however, will differ upon this point. At the present time the price of certified seed stock varies all the way from $1 to $3.50 per hundredweight—60 cents to $2.10 per bushel.

IMPORTANCE OF TUBER SHAPE.

Reasonable trueness of the tubers to varietal type is generally demanded by the purchaser of certified seed. And most writers who have dealt with the subject of good seed have always placed strong emphasis upon the importance of its being true to type. Rather recently, however, some scientific as well as practical growers have been disposed to regard tuber shape as being of less importance than has been previously supposed. They have come to regard tubers that have departed from the type as a result of unfavorable environmental conditions as being satisfactory for seed purposes.

As a result of a long-continued preachment of the undesirability of slightly off-type tubers for seed purposes many cars of otherwise high-grade seed stock have been annually rejected by the southern truck grower. This is particularly true in the case of conspicuously flattened and somewhat elongated tubers of the Irish Cobbler variety. The Irish Cobbler grower in the South has come to demand roundish tubers and is suspicious of the purity of seed stock containing flattened and somewhat elongated tubers and generally protests their acceptance as strictly first-class seed stock. In fact, he is inclined to regard the off-type tubers as Green Mountain. The only obvious way of correcting these firmly rooted convictions is to demonstrate experimentally that off-type tubers resulting from unfavorable soil, cultural, or climatic conditions are no more likely to produce off-type progeny than are normal-shaped ones. This statement, however, does not apply to off-type tubers resulting from disease; such tubers should not be planted. The spindle-tuber recently recognized by pathologists as a communicable disease is very similar in its method of transmission to that of leaf-roll and the mosaic disease. Figure 6, *A*, represents a fairly good example of spindle tubers. It is important, therefore, in the purchase of somewhat off-type seed potatoes to know whether the change in shape is really due to unfavorable environmental factors and not to disease.

CAREFUL HARVESTING AND STORAGE OF THE CROP.

The average grower does not fully appreciate the importance of using every means to prevent the mechanical injury of the tubers during the process of harvesting and storing. If the crop is grown on land containing a plenteous admixture of small stones the tubers are almost certain to be more severely injured in harvesting than when grown in a sandy loam soil. Hand digging is not always feasible, but it is believed that where small stones abound in the soil it will be desirable to harvest the home seed plat by hand. Much injury will be avoided if the seed stock designed for planting the field plat of the ensuing year is picked directly into crates in which it is allowed to remain throughout the storage period.

The storage conditions necessary to insure vigorous seed at planting time are more easily provided in the North than in the South. In the former region a well-constructed cellar, pit, or cave serves reasonably well. The main thing is to keep the room temperature sufficiently low to retard germination. The ideal seed tuber is one which has not wasted any of its stored-up energy by excessive loss through sprouting. (Fig. 7.) It should be firm, with the first sprouts just showing. Such tubers can be depended upon, if suitable conditions prevail, to start quickly when planted and to make a vigorous growth.

The general practice among southern growers of securing seed from the North involves in the absence of suitable storage conditions one of two things: Either getting the seed potatoes late in the fall and holding them over in dugouts, pits, or cellars, with consequent sprouting before planting, or the risk of having the seed chilled, frozen, or overheated while in transit in midwinter. In the writer's opinion the greatest need of the large southern truck grower at present is that of suitable storage facilities for handling fall shipments of seed potatoes. As a purely economic proposition the proposed change ought to commend itself. In probably nine cases out of ten the difference in first cost of these potatoes as between fall and midwinter shipments would more than offset the extra cost of storage, while the added security from danger of chilling or freezing the shipment would still further compensate the grower.

For further particulars on storage, consult Farmers' Bulletin 847, entitled "Potato Storage and Storage Houses."

LARGE COMPARED WITH SMALL SEED TUBERS.

In seasons of short production and consequent high prices for table stock, the question is frequently raised as to the advisability of using the small unsalable tubers for seed. The answer to this question is that it is always unsafe to use small tubers for seed purposes unless one is absolutely certain that they have been produced by healthy, vigorous, and productive plants. As a result of some experimental study of this question by Ballou and Gourley[4] it was found that the use of large tubers gave—

(*a*) A very heavy, perhaps almost total, percentage of the high-producing strains.
(*b*) A heavy percentage of the average or moderate-yielding strains.
(*c*) A very small percentage of the inferior or low-producing strains.

[4] Ballou, F. H., and Gourley, J. H. I. The status of the potato growing industry in Ohio. II. Seasonal notes on potatoes. Ohio Agr. Exp. Sta. Bul. 218, p. 587. 1910.

The use of small potatoes gives—

(*a*) A very insignificant percentage of the superior or high-yielding strains.
(*b*) A small percentage of the average or moderate-yielding strains.
(*c*) A very heavy, almost total, percentage of the low-yielding or inferior strains.

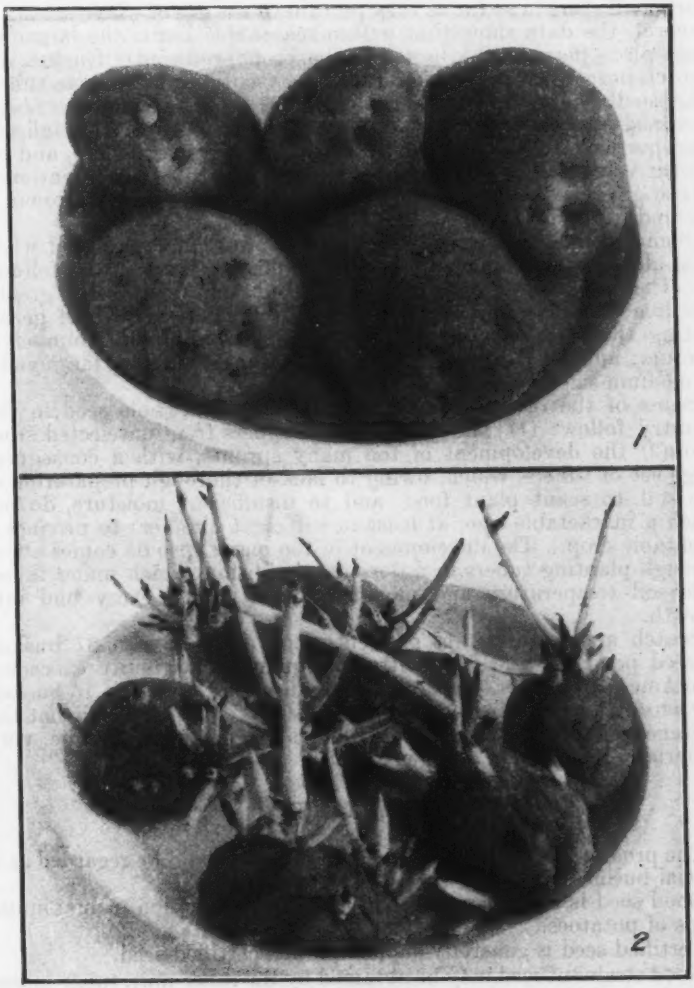

FIG. 7.—Potatoes for seed purposes, showing different stages of germination: 1, Desirable; 2, undesirable.

The use of small seed potatoes is only permissible when they are known to have been produced by strong, healthy, and productive plants. It is never advisable to use small tubers from the general mass produced from unselected stock.

WHOLE COMPARED WITH CUT SEED.[5]

Considerable attention has been paid to the subject of whole versus cut seed at various times by the State agricultural experiment stations. The data accumulated in these investigations are for the most part conflicting in so far as they pertain to the use of whole seed. In general, the data show that within reasonable limits the larger the seed piece planted the larger is the crop produced. English and Scotch potato growers almost without exception plant whole tubers. The seed used usually runs from 1¼ to 2¼ inches in diameter, being screened out of a crop which as a rule has been grown especially for seed purposes. They are harvested before they are mature, and but a relatively small proportion of the crop exceeds the size mentioned. These growers believe that an earlier and more vigorous growth is secured from immature tubers.

Some of the reasons why European growers have adopted whole seed and are succeeding in producing profitable crops are as follows: (1) They are assured of an almost perfect stand; (2) there is greater freedom from disease; (3) the almost universal practice of germinating their seed before planting insures a minimum number of sprouts; and (4) the greater fertility of their land makes large yields of medium-sized tubers possible.

Some of the reasons for failure in the use of whole seed in this country follow: (1) The use of small tubers from unselected stock and (2) the development of too many sprouts, with a consequent large set of tubers, which, owing to lack of thorough preparation of the soil, to scant plant food, and to insufficient moisture, do not reach a marketable size, at least in sufficient numbers to produce a profitable crop. The development of too many sprouts comes about through planting tubers in a dormant condition, which under favorable soil temperature and moisture starts almost every bud into growth.

Scotch and Irish potato growers plant not less than 37 bushels of seed per acre, and frequently this quantity is greatly exceeded. The American grower, on the other hand, plants from 7 to 16 bushels per acre, with an average of 9 to 11 bushels. It is believed that the average potato production of the United States would be very materially increased if a larger quantity of seed were used.

SUMMARY.

The production of high-grade seed potatoes should be regarded as a special business.

Good seed is a determining factor in the production of maximum crops of potatoes.

Certified seed is generally superior to noncertified seed.

Good strains of seed may be obtained by the tuber-unit, tuber-index, hill-selection, mass-selection, field-roguing, or strain-test methods through the process of elimination.

Like produces like. If tubers from unproductive, weak, or diseased plants are planted, a poor harvest will be reaped. Use seed from productive plants.

[5] Stuart, W., and others. Size of potato sets: Comparisons of whole and cut seed. U. S. Dept. Agr. Bul. 1248, 43 pp., illus. 1924.

Purity of seed stock is an essential quality of good seed. Serious losses are sustained by the grower through mixtures.

Good seed can not be produced unless the growing plants are well cared for and the strain of seed planted was a good one.

A more liberal use of good seed would materially increase the average production per acre.

All seed should be disinfected before planting.

Experimental evidence does not indicate that whole seed is superior to cut seed, at least so far as it relates to the United States.

Good storage facilities are essential to insure sound, firm seed at planting time.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

November 15, 1927

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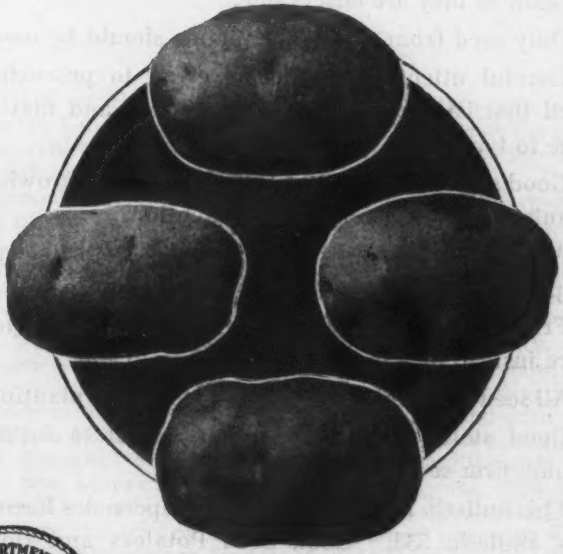
FARMERS' BULLETIN No. 1332 rev. June 1929

Rev.ed. follows

SEED POTATOES AND HOW TO PRODUCE THEM



THE AVERAGE PRODUCTION per acre of potatoes in the United States is very much lower than in Canada, Great Britain, and European countries outside of Italy.

One of the reasons for the lower production in the United States is that less attention has been given to the character of the seed. Good seed is one of the determining factors in the production of maximum crops of potatoes.

The use of high-grade seed would increase the returns from the potato crop of the country by many millions of dollars.

The quality of the seed may be improved through the removal of all diseased, weak, or off-type plants as soon as they are observable.

Only seed from productive plants should be used.

Careful attention should be given to procuring seed that is free from varietal mixture and that is true to type.

Good seed can not be produced unless the growing plants are given good cultural attention.

As a rule the quantity of seed used is not sufficient to produce a maximum crop.

From 15 to 18 bushels of seed should be used per acre instead of 9 to 11, as at the present time.

All seed stock should be disinfected before planting.

Good storage conditions are essential to insure sound, firm seed at planting time.

This bulletin is a revision of and supersedes Farmers' Bulletin 533, "Good Seed Potatoes and How to Produce Them."

Washington, D. C. Issued May, 1923; revised June, 1929

SEED POTATOES AND HOW TO PRODUCE THEM

By WILLIAM STUART, *Senior Horticulturist, Office of Horticultural Crops and Diseases, Bureau of Plant Industry*

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YIELDS OF POTATOES

A STUDY of the statistical data upon potato-crop production in the United States for the last 60 years reveals the interesting fact that relatively little gain in production per acre has been made except during the last few years of this period.

To minimize partially seasonal variations in yield per acre the 60-year period [1] has been divided into twelve 5-year cycles and the average production of each cycle compared. During the first 5-year cycle, 1868 to 1872, the average yield per acre was 94.5 bushels, whereas in the last 5-year period it was 113.7, or a gain of approximately 20.3 per cent. The averages for the twelve 5-year cycles are 94.5, 88.1, 77.9, 76.7, 74.0, 79.9, 82.2, 96.3, 96.5, 96.0, 98.9, and 113.7 bushels per acre, respectively. A study of these data show that there was a very appreciable and more or less gradual decline in production per acre during the second, third, fourth, and fifth cycles, or from 1875 to 1892, and that during the next three cycles there was a decided increase. From this period until the 1918–1922 cycle the increase was a very nominal one, but during the 1923–1927 cycle the increase was very marked. In fact, as compared with the 1918–1922 acreage, it shows an increase of nearly 15 per cent.

It is possible to account for this striking increase in production per acre only by assuming that it is largely due to a more general use of

[1] The statistical data upon which these studies are based were obtained for the years 1868 to 1888 from the United States Department of Agriculture Yearbook for 1917, p. 657; for 1889 to 1895 from the 1920 Yearbook, p. 617; for 1896 to 1920 from the 1921 Yearbook, p. 583; and for 1921 to 1922 from the Dec. 23, 1922, issue of the United States Department of Agriculture Weather, Crops and Markets publication, p. 565; for 1923, 1924, and 1925 from the 1926 Yearbook, p. 934; and for 1926 and 1927 from Crops and Markets, Dec., 1927, p. 460.

certified seed potatoes and to the gradual improvement in the quality of the seed produced. The total average bushel production in the United States in the 5-year cycle 1868 to 1872 was 117,745,800, whereas in the last two periods, 1918–1922 and 1923–1927, the production was 390,615,600 and 383,526,400 bushels, respectively. Expressed in percentages, the increases were 231 and 225.7 per cent. During this same period the acreage increases were 217 and 154.5 per cent, respectively. These data show rather conclusively that up to the last 5-year period increased total production has been due to increased acreage rather than to increase yield per acre. This does not apply to the last cycle, 1923 to 1927, as it is clearly evident that the increased production was due to a larger acre yield brought about by improved cultural practices.

Table 1 and the accompanying diagrams (figs. 1 to 3) show the average acre yields, the farm price per bushel, the acreage grown, and the total production of potatoes, while Figure 4 shows the population of the United States during the eleven 5-year cycles studied. In the construction of these diagrams it has not been feasible to employ the same scale in any two of them, owing to the great difference in the magnitude of the figures treated. A careful study of the first diagram (fig. 1), in which the acreage yield and farm price per bushel are given, shows that the acreage-production curve, if drawn on the chart, would somewhat resemble the curve of a scimitar blade, in which the extreme ends of the blade represent the maximum yields for each half of the curve.

TABLE 1.—*Averages of acreage, production, and farm values of potatoes in 5-year periods from 1868 to 1927, inclusive*

Five-year period	Number of acres	Production (bushels)		Farm value on Dec. 1	
		Total	Per acre	Total	Per bushel (cents)
1868 to 1872	1,246,200	117,745,800	94.5	$64,123,600	54.5
1873 to 1877	1,529,800	134,773,200	88.1	68,665,600	50.9
1878 to 1882	1,934,200	150,706,200	77.9	85,547,200	56.8
1883 to 1887	2,284,000	175,197,800	76.7	82,295,000	46.9
1888 to 1892	2,633,800	194,939,400	74.0	93,012,600	47.7
1893 to 1897	2,900,400	231,757,800	79.9	95,258,400	41.1
1898 to 1902	2,968,200	243,866,400	82.2	117,671,600	48.3
1903 to 1907	3,213,200	309,568,200	96.3	170,652,800	55.1
1908 to 1912	3,644,400	351,793,800	96.5	213,038,200	60.6
1913 to 1917	3,812,400	366,045,600	96.0	322,292,400	88.0
1918 to 1922	3,948,400	390,615,600	98.9	425,975,400	109.1
1923 to 1927 [1]	3,372,400	383,526,400	113.7	416,232,000	108.5

[1] Data for 1927 are subject to correction.

The gradual decline in yields during the first half of this period is thought to be largely due to the following factors:

The ravages occasioned by the Colorado potato beetle during the early period of its invasion of the eastern United States.

The financial depressions of 1877 and 1893, which brought about a well-marked decline in agriculture in New England, New York, and the other heavy potato-producing areas of the northeastern United States.

A gradual depletion of soil fertility.

Of the factors which have checked the downward tendency and contributed most largely toward a return to the old production level the following are thought to have been most potent:

The influence of the agricultural experiment stations, agricultural colleges, and the United States Department of Agriculture through experimentations, demonstration, and the dissemination of literature.

The influence of the Bordeaux-mixture treatment in the control of fungous diseases affecting the potato.

The development of special potato-growing sections, as, for example, Aroostook County, Me., the Atlantic Coastal Plain trucking region, the Greeley and Carbondale districts of Colorado, and many other areas, in which the average yield is approximately from two to three times the general average for the United States.

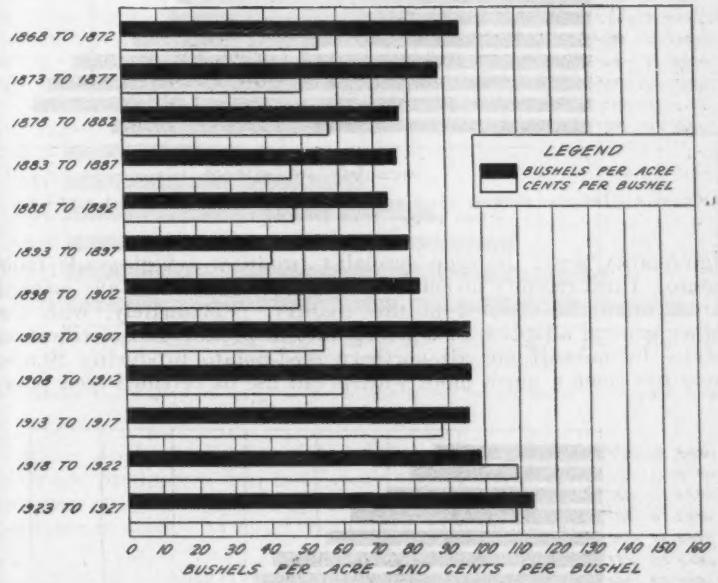

FIGURE 1.—Diagram showing the average number of bushels per acre and the average farm price per bushel of potatoes grown in the United States by 5-year periods from 1868 to 1927

Figures 1 to 4 show a comparison of the relation of increased production to a constantly increasing population. The diagrams show that under normal conditions production is keeping pace with population. Crop shortages are, therefore, the result of abnormal or unfavorable conditions.

In comparing the average crop production of potatoes in the United States with that of Great Britain, one is impressed with the fact that generally speaking we have much yet to learn before we can raise our average to that of that country. During the years 1901 to 1910, inclusive, the average acre yield in Great Britain was approximately 200 bushels, while that in the United States was not quite 93 bushels.

Of the many causes that produce a low average yield in the United States, poor seed is thought to play an important part. As a rule

the North American potato grower does not pay as careful attention to the seed potatoes he plants as does the European grower. The quality of seed demanded by European potato growers has been largely responsible for their differentiation into seed specialists and crop specialists. The seed specialist makes a business of producing

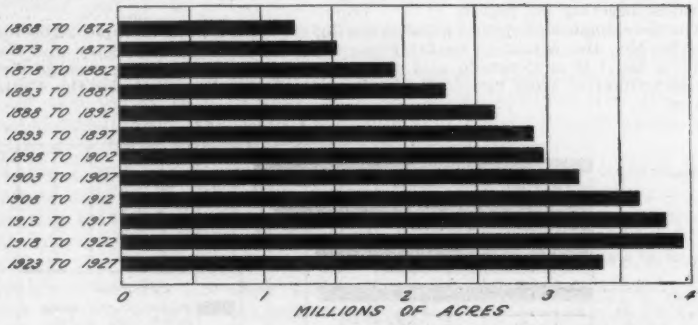

FIGURE 2.—Diagram showing the average potato acreage of the United States by 5-year periods from 1868 to 1927

high-quality seed; the crop specialist produces a high-grade table potato. Until recently no such differentiation, at least to any marked extent, could be claimed in this country. Fortunately, with the rather general adoption of a seed-potato inspection and certification service by most if not all northern seed-potato producing States, there has come a much more widespread use of certified seed pota-

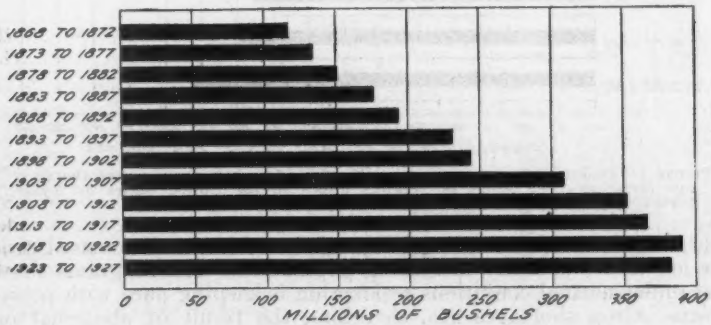

FIGURE 3.—Diagram showing the average potato production of the United States by 5-year periods from 1868 to 1927

toes and as a result a keener appreciation on the part of progressive growers of the real importance of good seed stock. This is resulting in an increased demand for certified seed potatoes, in consequence of which those who are engaged in the production of high-class seed are receiving a handsome premium for it.

WHAT CONSTITUTES GOOD SEED

Two factors are involved in the consideration of good seed potatoes: (1) The physical or outward appearance of the tubers and (2) the heritable or transmissible characters of the stock. The first involves the purity and maturity of the stock, uniformity in size and shape of the tubers, brightness of skin, firmness of flesh with first sprouts just showing, and freedom from scab, Rhizoctonia, late blight, or other tuber-decay diseases. The second factor deals with nonobservable characters and is by far the more important one, as it involves the presence or absence of the virus diseases causing mosaic, leaf roll, spindle tuber, streak, and yellow dwarf. Freedom from the virus diseases is an important consideration and can only be assured through personal inspection of the growing plants from which the seed was obtained or by the purchase of reliably certified stock. If in any given year it were possible to plant the entire potato acreage of the United States with first-class seed stock the total pro-

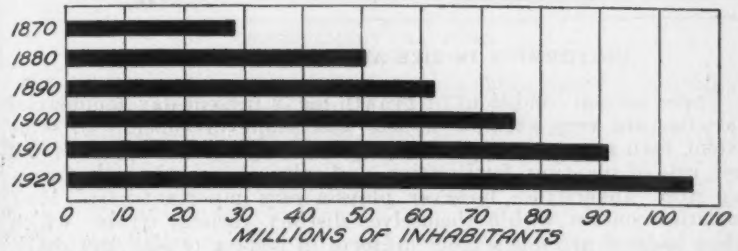

FIGURE 4.—Diagram showing the population of the United States by decades from 1870 to 1920

duction would be increased from 10 to 25 per cent. Based on the average production for the 5-year period from 1918 to 1922, this increase would represent from 39 to 97½ million bushels, or an increase in money value of $40,333,000 to $106,333,000.

CERTIFIED AND UNCERTIFIED SEED

The rapid increase in acreage and production of certified seed potatoes, together with the premium over uncertified seed demanded by the grower for such stock, has made it necessary to demonstrate its superiority over ordinary seed. In the early and consequently developmental period of seed certification the producers' claims of superiority were not sufficiently well supported by experimental evidence to make them convincing. To-day there is abundant evidence of the general superiority of certified over uncertified seed potatoes. In a paper presented at the 1924 annual meeting of the Potato Association of America, H. C. Moore, of the Michigan Agricultural College, submitted data covering actual comparative tests by a large number of independent investigators, as shown in Table 2.[2]

[2] MOORE, H. C. EVIDENCE THAT CERTIFIED SEED IS IMPROVED SEED. Proc. 11th Ann. Meeting, Potato Assoc. America, 1924, p. 28. 1925.

These and many other data serve to emphasize the value of high-grade seed. They also indicate the general superiority of certified over noncertified stocks as a source of good seed.

TABLE 2.—*Comparative tests of potato yields, showing the advantage of using certified seed*

Location of tests	Number of tests or reports	Average increase in yields per acre (bushels)	Location of tests	Number of tests or reports	Average increase in yields per acre (bushels)
Canada (8 Provinces)	15	88	Michigan	314	73
Connecticut	144	53	Missouri	46	43
Delaware	21	83	Montana	2	219
Illinois	15	47	Nebraska	64	141
Indiana	9,740	44	New York	68	76
Kansas	11	41	Ohio	168	48
Kentucky	220	42	Oregon	3	150
Louisiana	31	42	Pennsylvania	87	41
Maine	279	83	South Carolina	8	31
Massachusetts		75			

UNIFORMITY IN SIZE AND SHAPE OF TUBERS

Under normal conditions of growth many present-day commercial varieties are very variable in size and shape of tuber. To some extent both size and shape are determined by the character of the soil, rate of planting, fertilization, and cultural care given the growing crop. Inheritance, however, plays a very important part. Most varieties contain within themselves distinct varietal strains which when isolated are much more uniform in respect to size and shape than the variety itself. Other things being equal, the variety or varietal strain that produces the greatest number of fair-sized shapely tubers and the smallest number of ill-shaped and small tubers should prove the most valuable, because it involves less waste to both the grower and the consumer. It is particularly important at present that such strains be developed, because there is an increasing demand for fancy table stock to satisfy the requirements of a large and discriminating class of consumers who are insisting on greater uniformity in size and shape and are willing to pay a premium on such grades.

DEVELOPMENT OF HIGH-GRADE SEED POTATOES

The successful production of high-grade seed potatoes is very largely dependent upon the following factors: (1) Starting with a good strain; (2) the proper treatment of the seed; (3) thorough preparation and proper fertilization of the soil; (4) the following of the best cultural practices, including protection against insect and fungous pests; (5) the elimination of all mixtures and all diseased or weak plants; and (6) the careful harvesting and proper storage of the crop.

SECURING A GOOD STRAIN OF SEED

If the strain of seed being used is lacking in vigor, it is generally advisable to discard it and purchase a new lot from some reliable grower having superior stock. This suggestion is made as the re-

sult of a rather wide experience in trying to improve poor strains of potatoes through selection methods. Such attempts have usually resulted in failure, and it is felt that as a rule much more satisfactory progress can be made by starting with a new strain. Further improvement can usually be secured through selection.

IMPROVEMENT BY SELECTION

The improvement of seed potatoes by selective processes has long engaged the attention of the potato grower. Recent experimental evidence seems to indicate that the possibilities of improving potato seed stock by selective processes alone are not as great as many writers upon this subject have claimed. To those who have devoted much time and effort to the improvement of the potato by selection it would appear that the chances of finding superior yielding true-to-type strains within a variety are not as great as has been believed. The chief advantages to be derived from seed-potato selection practices are the elimination of diseased and weak plants and the removal of varietal mixtures.

IMPROVEMENT PRACTICES

Six improvement practices may be used in obtaining a commercially desirable strain of potatoes, namely: (1) The tuber-indexing method, (2) tuber-unit method, (3) hill selection, (4) mass selection, (5) field roguing, and (6) strain testing.

TUBER-INDEXING METHOD

The tuber-indexing method of seed-potato improvement is the most recent as well as most effective method of eliminating diseased, weak, and low-yielding potato tubers from seed stock intended for planting in the seed plot. It is usually done during the winter season. The usual procedure in the employment of this method is to select as many tubers weighing from 7 to 9 ounces or thereabouts as greenhouse, hotbed, or outdoor space will permit. The next step is to number each tuber for identification purposes and then remove a seed piece or set from each one, preferably from the seed end, although any strong eye will serve the purpose. This set is then put in a suitable-sized pot (the 3½ or 4 inch size is satisfactory), or it may be planted in a greenhouse bench or hotbed. In either case the pot or set in the bench must be labeled with the number of the tuber from which it was taken. The plants produced from these seed pieces are carefully observed for the presence of virus diseases such as the various types of mosaic, leaf roll, spindle tuber, giant hill, and yellow dwarf. All plants showing the presence of any of the diseases mentioned as well as any sign of weakness are noted and the seed tuber from which the set was taken is discarded. In this way, by close observance of the plants, it is possible to get rid of most if not all of the diseased tubers prior to planting them.

The extent to which this work can be conducted in the North, except in regions where a late or fall crop of potatoes can be grown, is necessarily limited to the greenhouse or hotbed space available for the work. Where a fall or second crop is grown, as in southern

New Jersey, the Eastern Shore of Maryland or Virginia, and practically all of the Southern States, it is possible to practice the tuber-indexing method with the spring crop by planting the set from the numbered tuber in the open field and properly labeling it. Readings can be taken during the growing season in ample time for a second-crop planting of indexed tubers that are apparently free from disease as well as from any inherent weakness. By undertaking such work in the far South it would be possible to grow the indexed sets to full maturity before the normal planting period in the North. In fact, certain State seed certification agencies are now resorting to this practice in order to get a "reading" on the behavior of their certified strains of seed potatoes. It is believed that the day is not far distant when most of the States offering seed certification will be practicing this method of seed-potato improvement. The tubers found to be free from disease are planted at the proper time in a seed plot by themselves on the tuber-unit basis in order to make it easy to identify the presence of disease in the plants from any infected tuber that may have escaped the observer of the tuber-indexed set. From this point the same methods are practiced as in the tuber-unit method, the description of which follows.

TUBER-UNIT METHOD[8]

The tuber-unit method, as now generally understood, consists in selecting from the seed bin before planting time a considerable number of the most perfectly shaped tubers ranging from 6 to 8 ounces in weight. In planting, these tubers are quartered, as dropped, into parts as nearly equal as possible, by splitting the bud-eye cluster twice from seed to stem end of the tuber. In other words, the tuber is cut through its longitudinal axis. The four pieces of each tuber are dropped consecutively in the row at a distance of 10 to 12 inches apart in the furrow. All tubers showing discoloration of the flesh or other evidence of disease should be rejected. By allowing an additional spacing between sets of fours, the four plants from each tuber are definitely isolated from adjoining ones and the grower can readily observe any variation in vigor and uniformity among the various units planted. This method also enables him to detect any mixtures that may occur in the variety. All mixtures should be removed at once. By marking the units that appear to be the most uniform in size, vigor, and type when the plants are still in vigorous growth, the first step in selection has been accomplished. At digging time the product of each unit is separately harvested and a further selection made from the marked units of all tubers which most nearly approach the size, shape, and smoothness desired. The selected tubers of each unit should be separately placed in small sacks, preferably cotton or burlap, numbered with both field and unit numbers, and stored to await further examination. The final examination should produce data on the number and weight of merchantable and unmerchantable tubers and their general conformity in size, shape, and smoothness of the type desired. From

[8] For further information concerning the arrangement of a tuber-unit selection plot and a convenient system of note taking, see the following publication: STUART, WILLIAM. THE "TUBER-UNIT" METHOD OF SEED-POTATO IMPROVEMENT. U. S. Dept. Agr., Bur. Plant Indus. Cir. 113, pp. 25–31, 2 figs. 1913.

each of the units retained 10 of the best tubers should be selected for the next season's planting.

It is desirable to maintain the study of each selection on the tuber-unit basis the following season, because it permits a more accurate comparison of the behavior of each. The 10 selected tubers from each original unit will give 40 plants for study the second year. All selections which do not produce a reasonably uniform lot of plants should be marked for rejection. At harvest time the progeny of each selection should be kept by itself and the same data recorded as those taken on the crop grown from the original tuber unit. Only the products from such 40-hill rows as meet the most rigid requirements should be retained. The further conduct of the work will consist in

FIGURE 5.—Progeny of a mosaic-infected potato plant of the Triumph variety on the left (A) and of a healthy plant on the right (B). Bin selection of such seed would result in taking at least two tubers from the mosaic plant. If small tubers were used all would come from diseased plants. In hill-selection work the progeny of plant B should be saved

the multiplication of the selected strains for field planting and the elimination of weak plants.

HILL SELECTION

The hill-selection method consists in marking the most promising plants during the growing season and at harvesting time saving only those that give the greatest promise. (Figs. 5 and 6.) The progeny of each hill should be kept separate and the same data taken as outlined for the tuber unit. Plant on the tuber-unit or progeny-row basis the following season. For the sake of uniformity a definite number of tubers (five or more) should be planted from each hill selection. Subsequent procedure should follow the methods given for tuber-unit work.

MASS SELECTION

Mass selection differs from hill selection in only one respect, which is that the tubers from the individually selected plants are not kept separate. Generally those who practice mass selection do not go to the trouble of marking promising individual plants during the growing season, but simply go through the field before harvesting the whole crop and dig by hand as many plants as may be desired to secure the necessary quantity of seed that show the desired vigor and stem characters thought to be correlated with productiveness, trueness to type, and uniformity in size of tubers of the particular variety grown.

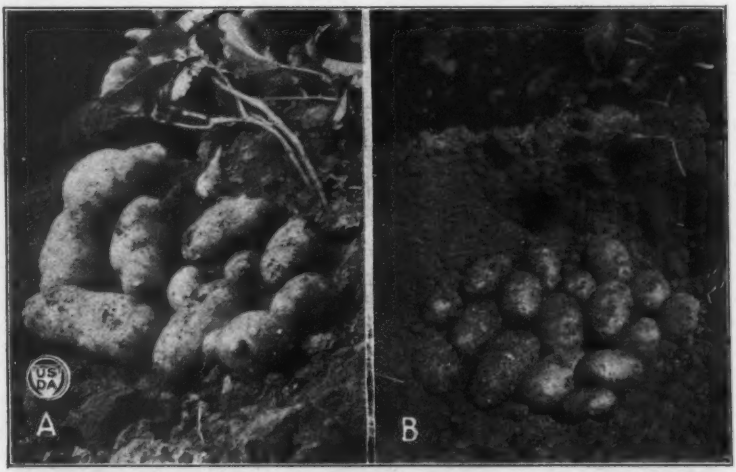

FIGURE 6.—Progeny from abnormal (A) and normal (B) plants of the Russet Burbank potato. Plant A is known in the West as a degenerate or run-out plant, and the disease with which it is affected is probably identical with that recently termed "spindle tuber." It is a communicable disease and may become serious. In hill-selection work the progeny of plants such as B should be saved

FIELD ROGUING

Improvement of the seed stock through field roguing consists in the removal of all diseased, weak, off-type, or varietal-mixture plants during the growing season. The successful removal of such plants does not necessarily involve an intimate knowledge of the various diseases affecting the potato, but it does require that the person doing the roguing be able to tell whether a plant is normal or abnormal in appearance. A sufficient field area should be rogued the first year to provide the quantity of seed necessary to plant the full acreage to be grown the ensuing season. The area to be rogued should be gone over at least three times during the growing season, to insure the removal of all plants affected with transferable diseases, such as mosaic and leaf roll, as soon as their presence can be detected. In the field-roguing method no attempt is made to select the progeny of individual plants at harvesting time, the whole crop being dug and all desirable seed stock gathered and stored in bulk.

STRAIN TESTING

The improvement of seed potatoes by the strain test, or, as it might more properly be termed, the "source-of-seed test" method, consists in securing as many desirable lots as possible of seed stock of the same variety from different growers throughout a given district or State, or even from various States, and carefully studying their behavior when grown side by side under identical soil and cultural conditions. Experimental studies by this method of seed improvement have demonstrated that some lots or strains of seed stock are far superior to others; in fact, differences in yield of more than 100 bushels per acre have been noted between the lowest and the highest yielding strains. Furthermore, it has been conclusively demonstrated by numerous trials that these yields were not accidental, but that in practically every instance the high-yielding strains have consistently given larger yields wherever tested.

The improvement of seed stock by this method does not consist in the actual isolation and development of a strain from a given variety, but rather in locating, as it were, by comparative tests the really superior sources of seed stock. The actual improvement accomplished is measured by the success attending one's efforts in getting live, up-to-date growers to discard their inferior strains and purchase the superior one, as shown by the tests made.

The practical operation of such a movement may be emphasized by stating that in 1921 more than 100 potato growers in Wisconsin grew seed stock of a superior strain of Triumph potatoes located in this manner in 1918.

It should be remembered that, whatever selection practice is pursued, the fields devoted to the production of high-quality seed must be carefully rogued if the vigor of the seed stock is to be maintained.

RELATIVE MERITS OF PRECEDING PRACTICES

A careful consideration of all the experimental evidence at hand would seem to justify the conclusion that in the hands of an especially trained individual the tuber-indexing method is without doubt the most effective for the elimination of diseased tubers and for the creation of foundation stock from which to produce high-class seed stock. The tuber-unit method is the next most promising procedure to follow. When the tuber-unit method is practiced in connection with that of hill selection it should prove much more effective than when used in connection with bin-selected stock. The first three methods can be recommended only to those growers and specialists who are capable of giving the necessary thought and time to produce results. Mass selection and field roguing present greater possibilities in the hands of the average grower who does not have the time or the inclination to give the care that is required for best results. Strain testing is not generally possible to the commercial grower.

REQUIREMENTS FOR SUCCESS

The only requirements for the successful practice of the tuber-unit, hill-selection, and mass-selection methods of seed-potato improvement are a reasonable degree of painstaking effort on the part of the grower, some 12-inch garden labels, a small pair of balances,

a sufficient number of small sacks, and a safe place in which to store the selected tubers until required for the next season's planting. In addition to this, the grower should have a breeding plot in which each season's selections can be developed up to the point of field-planting stock. This selection or seed plot should be located at as great a distance from the commercial potato field as possible, in order to secure the greatest degree of isolation that is feasible.

ISOLATION

Heretofore the problem of isolation has not received due consideration. This was largely owing to the fact that the seriousness of such diseases as mosaic, leaf roll, curly dwarf, streak, and spindle tuber has only recently come to be recognized. The fact that all of these diseases are readily transmitted from diseased to healthy plants through the instrumentality of plant lice or aphids and the further fact that as yet there is no reliable information as to the distance that insects may transport these diseases suggest as complete isolation of the seed plot as possible.

The latest suggestion in regard to the production of seed potatoes under isolation is that each variety be grown separately, as it has been found that stock of certain varieties supposed to be free from mosaic have served as disease carriers to more susceptible varieties. For example, it is not desirable to grow the Irish Cobbler adjacent to the Green Mountain intended for certification, as the former may carry the mosaic virus without expressing it. The danger from contamination of the healthy Green Mountain strain by the Irish Cobbler is considered sufficiently great by some seed-certification agencies to cause them to refuse to consider stock thus grown as eligible for certification. The ultimate success of the seed plot in so far as the elimination of tuber-borne diseases is concerned rests largely upon the ability of the grower to recognize diseased plants and the promptness with which they are removed from the seed plot and destroyed. Frequent and thorough inspections of the seed plot are necessary to insure the largest possible reduction of diseased plants and to reduce the transmission of disease from diseased to healthy plants.

SEED TREATMENT

It is impossible to produce high-grade seed potatoes if the seed planted is infected with disease organisms capable of infecting the crop. The disinfection of the seed potatoes is therefore necessary if the best results are to follow. The two diseases for which seed potatoes are ordinarily treated are common scab and black scurf, or Rhizoctonia. The two disinfecting agents recommended for such treatment are formalin and corrosive sublimate (mercuric chloride, or bichloride of mercury). Formalin is a trade name for a 40 per cent solution of formaldehyde gas. Corrosive sublimate is a white crystalline poisonous compound which goes into solution very slowly in cold water but is readily dissolved in boiling hot water. In recent years the hot formaldehyde treatment of seed has been found to be much more effective against black scurf (Rhizoctonia) than the cold-solution

treatment, and it requires a much shorter period of immersion. The formulas recommended for these two disease disinfectants are as follows:

1. Formalin:
   a. Cold treatment:
   Formalin, 1 pint.
   Water, 30 gallons.
   b. Hot treatment:
   Formalin, 2 pints.
   Water, 30 gallons, heated to 125° F.

2. Corrosive sublimate, 4 ounces.
   Water, 30 gallons.

The period of treatment for formula 1, *a*, and for formula 2 is from 1½ to 2 hours when the seed is dormant and one-half to 1½ hours if the tubers are germinated. With formula 1, *b*, on account of the double strength of the solution and the higher temperature of the liquid, the period of treatment is cut to 4 or 5 minutes. In using the hot formaldehyde solution it is necessary to have a reliable thermometer and a well-controlled method of maintaining a uniform temperature throughout the treatment.

The treated tubers should on no account be allowed to come in contact with such receptacles as old sacks and barrels in which diseased seed has been handled, as these articles are almost certain to be sources of reinfection.

PREPARATION AND FERTILIZATION OF THE SOIL

Strong, vigorous plants can not be produced on land that has been poorly prepared or that is deficient in available plant food. Seed potatoes should be grown on land that has been deeply plowed and thoroughly prepared to receive the seed. It should be well supplied with organic matter and available plant food. A clover or alfalfa sod furnishes the organic matter and considerable of the plant food. Barnyard manures or commercial fertilizers, or both, will supply the additional plant food necessary to produce a good crop.

CAREFUL CULTURAL PRACTICES

The vigor of the seed stock produced is to a large extent dependent on the care given to the growing crop. Uniformity in the size of the tubers is to a large extent governed by the rate of planting. Closer planting should be practiced in the growing of seed than of table stock. Some growers in Aroostook County, Me., space their rows from 32 to 36 inches apart and the plants in the row 8 to 12 inches. The crop should be cultivated as frequently as may be necessary to provide the most suitable growing conditions.

Every effort should be made to protect the plants from injury by insect or fungous pests. Leaf-eating insects can be effectively controlled if the plants are thoroughly sprayed with arsenical poisons; sucking insects, with contact solutions, such as kerosene emulsion and nicotine; and fungous diseases, such as the early and late blights, with Bordeaux mixture. In every operation it should be remembered that whatever contributes to the health of the plant increases the vigor of the seed stock produced.

ELIMINATION OF VARIETAL MIXTURES AND DISEASED OR WEAK PLANTS

The vegetable-seed growers employ the term "roguing" to denote the process of removing all mixtures or off-type plants from the seed plot. As this term, when understood, is a brief and yet sufficiently descriptive way of indicating the process of eliminating all undesirable plants or "rogues," it is proposed to use it in this connection.

It is an easy matter to rogue a seed-improvement or selection plot during the growing season. Varietal mixtures are more easily detected when the plants are in bloom. Weak plants are usually apparent in the early stages of their growth, as are also certain types of diseases, such as mosaic and blackleg, although both may appear later. Plants infected with Rhizoctonia and Fusarium are usually not apparent until the latter part of the growing season. It is evident from these statements that in order to rogue the seed plot thoroughly it is necessary to make two or three examinations of the field or plot during the growing season. Further roguing should be done when the crop is harvested by discarding the progeny of all low-producing plants. (Fig. 5, A.)

MONETARY VALUE OF GOOD SEED POTATOES

The producer of high-grade seed potatoes is justly entitled to a fair monetary return for the special efforts he has made to produce quality seed stock. This is especially true where a seed plot is maintained year after year and the crop has been officially inspected and passed by a duly authorized seed-certification inspection officer. Just what increase in price over ordinary stock one is entitled to receive for such efforts and for the inspection fees involved is not an easy matter to determine. It is believed that a premium of 50 cents a bushel over the market price of table stock of the same variety is ordinarily sufficient to amply repay the grower. Opinions, however, will differ upon this point. At the present time, the price of certified seed stock varies all the way from $1 to $3.50 a hundredweight—60 cents to $2.10 a bushel.

IMPORTANCE OF TUBER SHAPE

Reasonable trueness of the tubers to varietal type is generally demanded by the purchaser of certified seed. Most writers who have dealt with the subject of good seed have always placed strong emphasis upon the importance of its being true to type. Rather recently, however, some scientific as well as practical growers have been disposed to regard tuber shape as being of less importance than has been previously supposed. They have come to regard tubers that have departed from the type as a result of unfavorable environmental conditions as being satisfactory for seed purposes.

As a result of a long-continued preachment of the undesirability of slightly off-type tubers for seed purposes, many cars of otherwise high-grade seed stock have been annually rejected by southern truck growers. This is particularly true in the case of conspicuously flattened and somewhat elongated tubers of the Irish Cobbler variety. The Irish Cobbler grower in the South has come to demand roundish

tubers and is suspicious of the purity of seed stock containing flattened and somewhat elongated tubers and generally protests their acceptance as strictly first-class seed stock. In fact, he is inclined to regard the off-type tubers as Green Mountain. The only obvious way of correcting these firmly rooted convictions is to demonstrate experimentally that off-type tubers resulting from unfavorable soil, cultural, or climatic conditions are no more likely to produce off-type progeny than are normal-shaped ones. This statement, however, does not apply to off-type tubers resulting from disease; such tubers should not be planted. The spindle tuber recently recognized by pathologists as a communicable disease is very similar in its method of transmission to leaf roll and the mosaic disease. Figure 6, A, represents a fairly good example of spindle tubers. It is important, therefore, in the purchase of somewhat off-type seed potatoes to know whether the change in shape is really due to unfavorable environmental factors and not to disease.

CAREFUL HARVESTING AND STORAGE OF THE CROP

The average grower does not fully appreciate the importance of using every means to prevent the mechanical injury of the tubers during the process of harvesting and storing. If the crop is grown on land containing a plenteous admixture of small stones, the tubers are almost certain to be more severely injured in harvesting than when grown in a sandy loam soil. Hand digging is not always feasible, but it is believed that where small stones abound in the soil it will be desirable to harvest the home seed plot by hand. Much injury will be avoided if the seed stock designed for planting the field plot of the ensuing year is picked directly into crates in which it is allowed to remain throughout the storage period.

The storage conditions necessary to insure vigorous seed at planting time are more easily provided in the North than in the South. In the former region a well-constructed cellar, pit, or cave serves reasonably well. The main thing is to keep the room temperature sufficiently low to retard germination. The ideal seed tuber is one that has not wasted any of its stored-up energy by excessive loss through sprouting. (Fig. 7.) It should be firm, with the first sprouts just showing. Such tubers can be depended upon, if suitable conditions prevail, to start quickly when planted and to make a vigorous growth.

The general practice among southern growers of securing seed from the North involves, in the absence of suitable storage conditions, one of two things: Either getting the seed potatoes late in the fall and holding them over in dugouts, pits, or cellars, with consequent sprouting before planting, or the risk of having the seed chilled, frozen, or overheated while in transit in midwinter. In the writer's opinion the greatest need of the large southern truck grower at present is suitable storage facilities for handling fall shipments of seed potatoes. As a purely economic matter the proposed change ought to commend itself. In probably nine cases out of ten the difference in first cost of these potatoes as between fall and midwinter shipments would more than offset the extra cost of storage,

while the added security from danger of chilling or freezing the shipment would still further compensate the grower.

For further particulars on storage, consult Farmers' Bulletin 847, "Potato Storage and Storage Houses."

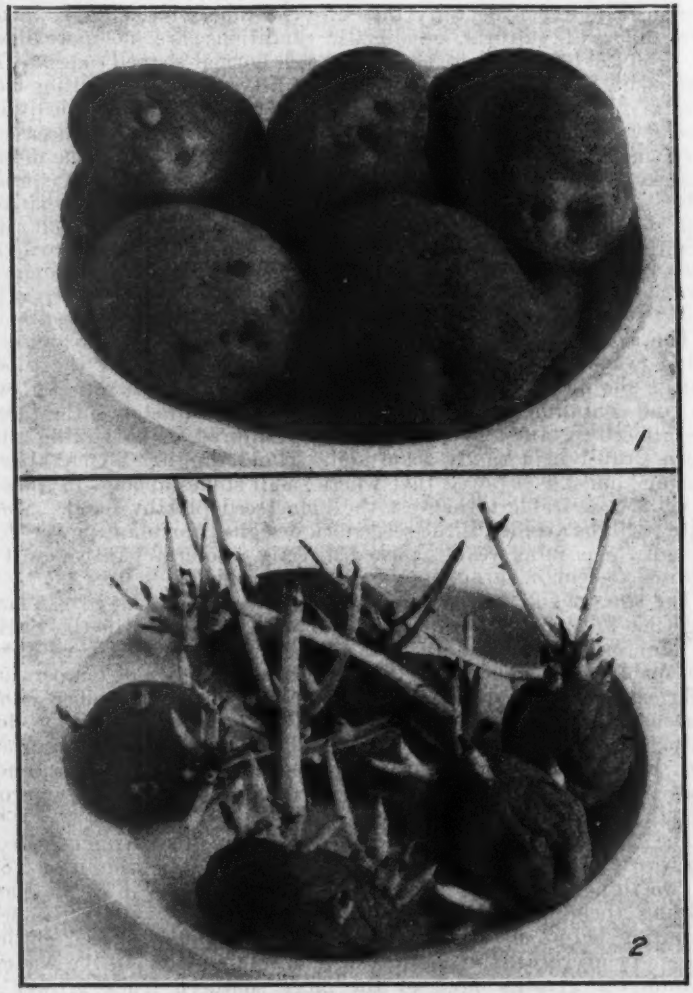

FIGURE 7.—Potatoes for seed purposes, showing different stages of germination: 1, Desirable; 2, undesirable

LARGE COMPARED WITH SMALL SEED TUBERS

In seasons of short production and consequent high prices for table stock, the question is frequently raised as to the advisability of using the small unsalable tubers for seed. The answer to this question

is that it is always unsafe to use small tubers for seed purposes unless one is absolutely certain that they have been produced by healthy, vigorous, and productive plants. As a result of some experimental study of this question by Ballou and Gourley [4] it was found that the use of large tubers gave—

(1) A very heavy, perhaps almost total, percentage of the high-producing strains.
(2) A heavy percentage of the average or moderate-yielding strains.
(3) A very small percentage of the inferior or low-producing strains.

The use of small potatoes gave—

(1) A very insignificant percentage of the superior or high-yielding strains.
(2) A small percentage of the average or moderate-yielding strains.
(3) A very heavy, almost total, percentage of the low-yielding or inferior strains.

The use of small seed potatoes is permissible only when they are known to have been produced by strong, healthy, and productive plants. It is never advisable to use small tubers from the general mass produced from unselected stock.

WHOLE COMPARED WITH CUT SEED [5]

Considerable attention has been paid to the subject of whole compared with cut seed at various times by the State agricultural experiment stations. The data accumulated in these investigations are for the most part conflicting in so far as they pertain to the use of whole seed. In general, the data show that within reasonable limits the larger the seed piece planted the larger is the crop produced. English and Scotch potato growers almost without exception plant whole tubers. The seed used usually runs from 1¼ to 2¼ inches in diameter, being screened out of a crop which as a rule has been grown especially for seed purposes. They are harvested before they are mature, and but a relatively small proportion of the crop exceeds the size mentioned. These growers believe that an earlier and more vigorous growth is secured from immature tubers.

Some of the reasons why European growers have adopted whole seed and are succeeding in producing profitable crops are as follows: (1) They are assured of an almost perfect stand; (2) there is greater freedom from disease; (3) the almost universal practice of germinating their seed before planting insures a minimum number of sprouts; and (4) the greater fertility of their land makes large yields of medium-sized tubers possible.

Some of the reasons for failure in the use of whole seed in this country are: (1) The use of small tubers from unselected stock and (2) the development of too many sprouts, with a consequent large set of tubers, which, owing to lack of thorough preparation of the soil, to scant plant food, and to insufficient moisture, do not reach a marketable size, at least in sufficient numbers to produce a profitable crop. The development of too many sprouts comes about through planting tubers in a dormant condition, which under favorable soil temperature and moisture starts almost every bud into growth.

[4] BALLOU, F. H., and GOURLEY, J. H. I. THE STATUS OF THE POTATO-GROWING INDUSTRY IN OHIO. II. SEASONAL NOTES ON POTATOES. Ohio Agr. Exp. Sta. Bul. 218, p. 587. 1910.

[5] STUART, W., and others. SIZE OF POTATO SETS: COMPARISONS OF WHOLE AND CUT SEED. U. S. Dept. Agr. Bul. 1248, 43 pp., illus. 1924.

Scotch and Irish potato growers plant not less than 37 bushels of seed per acre, and frequently this quantity is greatly exceeded. The American grower, on the other hand, plants from 7 to 16 bushels per acre, with an average of 9 to 11 bushels. It is believed that the average potato production of the United States would be very materially increased if a larger quantity of seed were used.

SUMMARY

The production of high-grade seed potatoes should be regarded as a special business.

Good seed is a determining factor in the production of maximum crops of potatoes.

Certified seed is generally superior to noncertified seed.

Good strains of seed may be obtained by the tuber-unit, tuber-index, hill-selection, mass-selection, field-roguing, or strain-test methods through the process of elimination.

Like produces like. If tubers from unproductive, weak, or diseased plants are planted, a poor harvest will be reaped. Use seed from productive plants.

Purity of seed stock is an essential quality of good seed. Serious losses are sustained by the grower through mixtures.

Good seed can not be produced unless the growing plants are well cared for and the strain of seed planted was a good one.

A more liberal use of good seed would materially increase the average production per acre.

All seed should be disinfected before planting.

Experimental evidence does not indicate that whole seed is superior to cut seed, at least so far as it relates to the United States.

Good storage facilities are essential to insure sound, firm seed at planting time.

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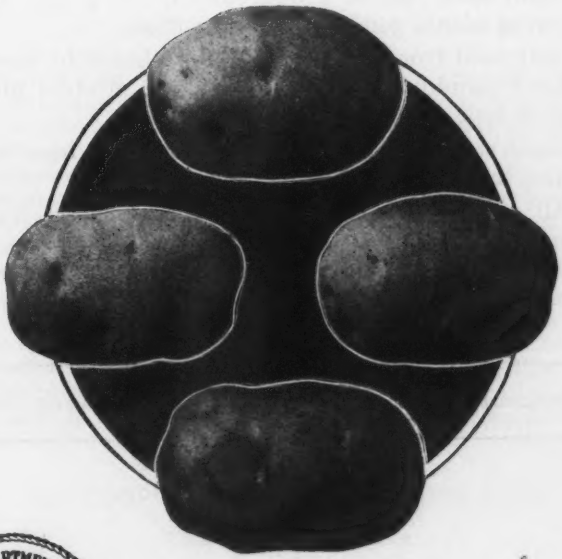
FARMERS' BULLETIN No. 1332

Rev.ed. follows

SEED POTATOES AND HOW TO PRODUCE THEM



THE IMPORTANCE of planting good seed potatoes is not appreciated as fully as it should be. Good seed is one of the determining factors in profitably producing maximum crops of potatoes.

The quality of the seed can be improved by removing all diseased, weak, or off-type plants as soon as they are observable.

Good seed can be produced only by giving the growing plants good cultural attention.

Only seed from productive plants should be used.

Seed should be free from varietal mixture and true to type.

Good storage conditions are essential in insuring sound, firm seed at planting time.

All seed stock should be disinfected before it is planted.

This bulletin is a revision of and supersedes Farmers' Bulletin 533, Good Seed Potatoes and How to Produce Them.

Washington, D. C. Issued May, 1923; revised April, 1933

SEED POTATOES AND HOW TO PRODUCE THEM

By WILLIAM STUART, *Senior Horticulturist, Division of Horticultural Crops and Diseases, Bureau of Plant Industry*

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IMPORTANCE OF GOOD SEED

THE USE OF GOOD SEED is especially important in lowering the unit cost of potato production. Lowering unit cost does not necessarily mean lowering the quality or the price of a bushel of potatoes, but, rather, furnishing a better product without increasing the cost of its production. The progressive potato-grower's aim should be to produce as many profitable bushels per acre as possible.

Two factors determine the quality of seed potatoes: (1) The physical or outward appearance of the tubers and (2) the heritable or transmissible characters of the stock. The first involves the purity and maturity of the stock, uniformity in size and shape of the tubers, brightness of skin, firmness of flesh with first sprouts just showing, and freedom from scab, Rhizoctonia, late blight, or other tuber-decay diseases. The second factor deals with nonobservable characters and is by far the more important, as it involves the presence or absence of the virus diseases causing mosaic, leaf roll, spindle tuber, streak, and yellow dwarf. Freedom from the virus diseases is important and can only be assured by inspection of the growing plants from which the seed was obtained or by the purchase of reliably certified stock.

DEVELOPMENT OF HIGH-GRADE SEED

SELECTION METHODS

The chief improvement to be made in seed-potato stocks by selection methods is the elimination of diseased and weak plants and of varietal mixtures. Experimental evidence seems to indicate that the possibilities of improving seed stock by selective practices alone are not so great as has been claimed, and that the chances of finding superior-yielding, true-to-type strains within a variety are more limited than was once believed.

Five methods of improvement may be used in obtaining a commercially desirable strain of potatoes: (1) The tuber-indexing method, (2) the tuber-unit method, (3) hill selection, (4) mass selection, and (5) field roguing.

TUBER-INDEXING METHOD

The tuber-indexing method of seed-potato improvement is the most recently devised and most effective method of eliminating diseased, weak, and low-yielding potato tubers from seed stock intended for planting in the seed plot. The work is usually done during the winter. The first step is to select as many tubers, each weighing from 7 to 9 ounces or thereabouts, as greenhouse, hotbed, or outdoor space will accommodate. The next step is to number each tuber for identification and then remove a seed piece or set from each, preferably from the seed end, although any strong eye will serve. This set is then put in a suitable-sized pot (the 3½ or 4 inch size is satisfactory), or it may be planted in a greenhouse bench or hotbed. In either case the set must be labeled with the number of the tuber from which it was taken. The plants produced from these seed pieces are carefully observed for virus diseases such as the various types of mosaic, leaf roll, spindle tuber, giant hill, and the yellow dwarf. All plants showing any of these diseases or any sign of weakness are noted, and the seed tubers from which the sets were taken are discarded. In this way it is possible to get rid of most if not all of the diseased tubers before planting them.

The best method of handling the mother tubers from which the index sets have been removed is to hold them for 10 days to 2 weeks in a temperature of 60° to 70° F., after which they may be held at 40° to 45° until planting. The higher temperature with relatively high humidity favors thorough healing of the cut surface.

The extent to which this work can be done in the North, except in regions where a late or fall crop of potatoes can be grown, is necessarily limited to the greenhouse or hotbed space available. Where a fall or second crop is grown, as in southern New Jersey, the Eastern Shore of Maryland and Virginia, and practically all of the Southern States, it is possible to practice the tuber-indexing method with the spring crop by planting the set from the numbered tuber in the open field and properly labeling it. Observations can be made during the growing season in ample time for a second-crop planting of indexed tubers that are apparently free from disease as well as from any inherent weakness. By doing such work in the far South it would be possible to grow the indexed sets to full maturity before the normal planting period in the North. In fact, certain State seed-certification agencies are now resorting to this practice in order to get a "reading" on the behavior of their certified strains of seed potatoes. At the usual planting time, the tubers found to be free from disease are planted in a seed plot by themselves, the pieces from each tuber being planted separately. It is then easy to identify, in the growing plants, any disease from an infected tuber that may have escaped the observer of the tuber-index set. From this point in the process the practices are the same as those under the tuber-unit method.

TUBER-UNIT METHOD[1]

The tuber-unit method consists in selecting from the seed bin before planting time a considerable number of the most perfectly shaped tubers ranging from 6 to 8 ounces in weight. In planting, these tubers are quartered, as dropped, into parts as nearly equal as possible, by splitting the bud-eye cluster twice from seed to stem end of the tuber. In other words, the tuber is cut through its longitudinal axis. The four pieces of each tuber are dropped consecutively in the row, 10 to 12 inches apart. All tubers showing discoloration of the flesh or other evidence of disease should be rejected. By allowing an additional spacing between sets of fours, the four plants from each tuber are definitely isolated and the grower can readily observe any variation in vigor and uniformity among the various units planted. This method also enables him to detect any mixtures in the variety. All mixtures should be removed at once. The units that appear most uniform in size, vigor, and type when the plants are still in vigorous growth are marked, and the first step in selection has been accomplished. At digging time the product of each unit is separately harvested and a further selection made from the marked units of all tubers which most nearly approach the size, shape, and smoothness desired. The selected tubers of each unit should be separately placed in small sacks, preferably cotton or burlap, numbered with both field and unit numbers, and stored to await further examination. The final examination should produce data on the number and weight of merchantable and unmerchantable tubers and their general conformity in size, shape, and smoothness to the type desired. From each of the units retained 10 of the best tubers should be selected for the next season's planting.

It is desirable to maintain the study of each selection on the tuber-unit basis the following season, because it permits a more accurate comparison of the behavior of each. The 10 selected tubers from each original unit will give 40 plants for study the second year. All selections which do not produce a reasonably uniform lot of plants should be rejected. At harvest time the progeny of each selection should be kept by itself and the same data recorded as those taken on the crop grown from the original tuber unit. Only the products from such 40-hill rows as meet the most rigid requirements should be retained. The further work will consist in multiplying the selected strains for field planting and eliminating the weak plants.

HILL SELECTION

The hill-selection method consists in marking the most promising plants during the growing season and at harvesting time saving only the progeny of the best. (Figs. 1 and 2.) The progeny of each hill should be kept separate and the same data taken as outlined for the tuber unit. Plant on the tuber-unit or progeny-row basis the following season. For the sake of uniformity a definite number of tubers (five or more) from each hill selection should be planted. Subsequent procedure should follow the practices given for the tuber-unit method.

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[1] For further information on the arrangement of a tuber-unit selection plot and a convenient system of note taking, see U. S. Dept. Agr., Bur. Plant Indus. Circ. 113, The "Tuber-Unit" Method of Seed-Potato Improvement.

FIGURE 1.—Progeny of (A) a mosaic-infected potato plant of the Triumph variety and (B) a healthy plant. Bin selection of such seed would result in taking at least two tubers from the mosaic plant. If small tubers were used all would come from diseased plants. In hill-selection work only the progeny of plant B would be saved

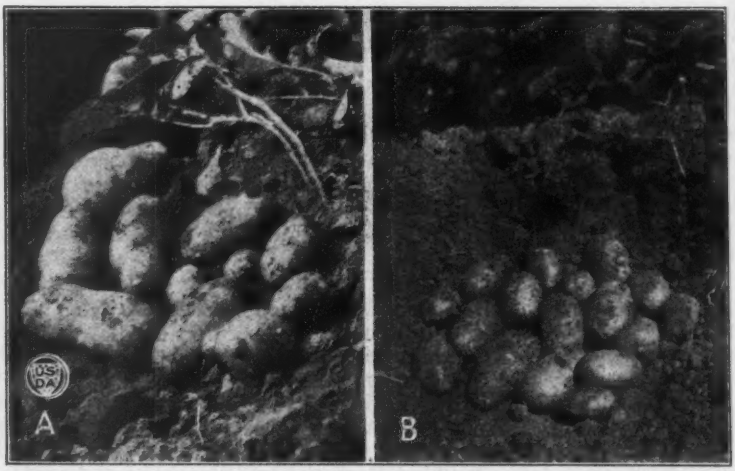

FIGURE 2.—Progeny from (A) abnormal and (B) normal plants of the Russet Burbank potato. Plant A is known in the West as a degenerate or run-out plant, and the disease with which it is affected is probably identical with that termed "spindle tuber." It is a communicable disease and may become serious. In hill-selection work only the progeny of plants such as B would be saved

MASS SELECTION

Mass selection differs from hill selection in only one respect, that is, the tubers from the individually selected plants are not kept separate. Generally growers who practice mass selection do not go to the trouble of marking promising individual plants during the growing season, but simply go through the field before harvesting the whole crop and dig by hand as many plants that show the desired vigor and stem characters thought to be correlated with productiveness, trueness to type, and uniformity in size of tubers of the particular variety grown, as may be desired to secure the necessary quantity of seed.

FIELD ROGUING

By "roguing" vegetable-seed growers mean improving the seed stock by the process of removing all "rogues"—diseased, weak, off-type, or varietally mixed plants—from the field or seed plot during the growing season, when the process is relatively easy. Roguing does not necessarily require an intimate knowledge of the various potato diseases, but it does call for the ability to tell whether a plant is normal or abnormal in appearance. Varietal mixtures are more easily detected when the plants are in bloom. Weak plants are usually easy to detect in the early stages of their growth, as are also certain types of disease such as mosaic and blackleg, although both weakness and disease may appear later. Infection with Rhizoctonia and Fusarium is usually not apparent until the latter part of the growing season. The area should be gone over at least three times during the growing season. In field roguing a sufficient area should be covered the first year to provide enough seed to plant the full acreage that is to be grown the ensuing season. When the crop of the seed plot is harvested, further roguing should be done by discarding the progeny of all low-producing plants. (Fig. 1, A.)

RELATIVE MERITS OF THE DIFFERENT METHODS

Careful consideration of all the experimental evidence at hand seems to justify the conclusion that in the hands of an especially trained individual the tuber-indexing method is without doubt the most effective process for eliminating diseased tubers and for creating foundation stock from which to produce high-class seed stock. The tuber-unit method is the next most promising. When it is practiced in connection with hill selection it should prove much more effective than when used in connection with bin-selected stock. The first three methods can be recommended only to those growers and specialists who are capable of giving the thought and time necessary to produce results. Mass selection and field roguing present greater possibilities in the hands of the average grower who does not have time or inclination to give the care required for best results.

The only requirements for the successful practice of the tuber-unit, hill-selection, and mass-selection methods are a reasonable degree of painstaking effort on the part of the grower, some 12-inch garden labels, a small pair of balances, a sufficient number of small sacks, a safe place in which to store the selected tubers until they are required for the next season's planting, and a breeding plot in which each season's selections can be developed into planting stock. The selection

or seed plot should be located as far from the commercial potato field as possible, in order to secure the greatest degree of isolation feasible.

ISOLATION

It is now recommended that in producing seed potatoes under isolation, each variety be grown separately, because it has been found that stocks of certain varieties supposed to be free from mosaic have served as carriers of disease to more susceptible varieties. For example, it is not desirable to grow the Irish Cobbler adjacent to the Green Mountain intended for certification, as the former may carry the mosaic virus without revealing it. Some seed-certification agencies consider the danger of the Irish Cobbler's contaminating the healthy Green Mountain variety so great that they refuse to certify Green Mountain stock near which Irish Cobbler has been grown. The ultimate success in using the isolated seed plot in eliminating tuber-borne diseases rests largely on the ability of the grower to recognize diseased plants and his promptness in removing them from the seed plot and destroying them. Heretofore, the factor of isolation has not received due consideration, largely because the seriousness of such diseases as mosaic, leaf roll, curly dwarf, streak, and spindle tuber had not been recognized. The fact that all of these diseases are readily transmitted from diseased to healthy plants through the instrumentality of plant lice or aphids and the further fact that as yet there is no reliable information on the distance over which insects may transport these diseases, suggest an isolation of the seed plot as complete as possible.

Frequent and thorough inspections of the seed plot are necessary to insure the largest possible elimination of diseased plants and to reduce the transmission of disease from diseased to healthy plants.

SEED TREATMENT

It is impossible to produce high-grade seed potatoes if the seed planted is infected with disease organisms capable of infecting the crop. Disinfection of the seed potatoes is therefore necessary if the best results are to follow. The two diseases for which seed potatoes are ordinarily treated are common scab and black scurf, or Rhizoctonia. The two disinfecting agents recommended for such treatment are formalin and corrosive sublimate (mercuric chloride, or bichloride of mercury). Formalin is a trade name for a 40 per cent solution of formaldehyde gas. Corrosive sublimate is a white crystalline poisonous compound which goes into solution very slowly in cold water but is readily dissolved in boiling water. The hot-formaldehyde treatment of seed has been found much more effective against black scurf (Rhizoctonia) than the cold-solution treatment, and requires a much shorter period of immersion. The formulas recommended for these two disease disinfectants are:

1. Formalin:
   - *a*. Cold treatment:
     Formalin, 1 pint.
     Water, 30 gallons.
   - *b*. Hot treatment:
     Formalin, 2 pints.
     Water, 30 gallons, heated to 125° F.

2. Corrosive sublimate, 4 ounces.
   Water, 30 gallons.

The period of treatment for formula 1, *a*, and for formula 2 is from 1½ to 2 hours when the seed is dormant and one-half to 1½ hours if the tubers are germinated. With formula 1, *b*, on account of the double strength of the solution and the higher temperature of the liquid, the period of treatment is cut to 4 or 5 minutes. In using the hot formaldehyde solution it is necessary to have a reliable thermometer and a well-controlled method of maintaining a uniform temperature throughout the treatment.

The treated tubers should on no account be allowed to come in contact with such receptacles as sacks and barrels in which diseased seed has been handled, as these articles are almost certain to be sources of reinfection.[2]

SOIL PREPARATION AND CULTURAL PRACTICES

Strong, vigorous plants can not be produced on land that has been poorly prepared or that is deficient in available plant food. Seed potatoes should be grown on land that has been deeply plowed and thoroughly prepared to receive the seed. It should be well supplied with organic matter and available plant food. A clover or alfalfa sod furnishes the organic matter and considerable plant food. Barnyard manures or commercial fertilizers, or both, will supply the additional plant food necessary.

The vigor of the seed stock produced depends largely on the care given to the growing crop. Uniformity in the size of the tubers is largely governed by the rate of planting. Closer planting should be practiced in growing seed than in growing table stock. Some growers in Aroostook County, Me., space their rows 32 to 36 inches apart and the plants in the row 8 to 12 inches. The crop should be cultivated as frequently as may be necessary to provide the most suitable growing conditions.

The plants should be sprayed to prevent injury by insect or fungous pests. Leaf-eating insects can be effectively controlled by thorough spraying with arsenical poisons; sucking insects, with contact solutions, such as kerosene emulsion and nicotine; and fungous diseases, such as the early and late blights, with Bordeaux mixture. In every operation it should be remembered that whatever contributes to the health of the plant increases the vigor of the seed stock produced.

IMPORTANCE OF TUBER SHAPE AND SIZE

Reasonable trueness of the tubers to varietal type is generally demanded by the purchaser of certified seed. The Irish Cobbler grower in the South demands roundish tubers and is suspicious of the purity of seed stock that contains flattened and somewhat elongated tubers; he generally protests against accepting them as strictly first-class seed stock, and is inclined to regard the off-type tubers as Green Mountain.

However, some scientific workers and practical growers are now disposed to regard tuber shape as being less important than was previously supposed. They have come to regard tubers that have departed from the type because of unfavorable environmental conditions as being satisfactory for seed purposes, and as no more likely

[2] For more complete information on seed treatment, see U. S. Dept. Agr. Misc. Pub. No. 53, Disinfecting Seed Potatoes.

to produce off-type progeny than are normal-shaped tubers. This, however, does not apply to tubers that are off-type as a result of disease; such tubers should not be planted. The spindle tuber, now recognized as a communicable disease, is very similar to leaf roll and the mosaic disease in its method of transmission. Figure 2, A, pictures a fairly good example of spindle tubers. It is important, therefore, in purchasing somewhat off-type seed potatoes to know that the change in shape is really due to unfavorable environmental factors and not to disease.

In seasons of short production and consequent high prices for table stock, the question of whether it is advisable to use the small, unsalable tubers for seed is frequently raised. It is always unsafe to use small tubers for seed unless it is absolutely certain that they have been produced by healthy, vigorous, and productive plants. It is never advisable to use small tubers from the general production from unselected stock. Some experimental study of this subject by Ballou and Gourley [3] demonstrated that the planting of large tubers gave—

(1) A very high, sometimes almost total, percentage of the high-producing strains.
(2) A high percentage of the average or moderate-yielding strains.
(3) A very low percentage of the inferior or low-producing strains.

The planting of small tubers gave—

(1) A very insignificant percentage of the high-producing strains.
(2) A low percentage of the moderate-yielding strains.
(3) A very high, almost total, percentage of the low-yielding strains.

WHOLE SEED COMPARED WITH CUT SEED [4]

Experimental evidence does not indicate that whole tubers are better than cut tubers as seed, at least in the United States. The data, while conflicting, show that in general and with reasonable limits the larger the seeds planted, the larger the crop. If whole seed is to be planted, small tubers and those from unselected stock should not be used.

The tubers should be germinated before being planted, to insure a minimum number of sprouts. Planting dormant whole tubers causes too many sprouts to develop.

HARVESTING AND STORAGE

The importance of preventing mechanical injury of the tubers during harvesting and storing is not fully realized. If the land contains small stones, the tubers are almost certain to be more severely injured in harvesting than if they were grown in a sandy loam soil. Hand digging is not always feasible, but where small stones abound in the soil it is desirable to harvest the home seed plot by hand.

Much injury will be avoided if, when harvested, the seed stock designed for planting the field plot of the ensuing year is placed directly in crates in which it can remain throughout the storage period.

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[3] The Status of the Potato-Growing Industry in Ohio. II. Seasonal Notes on Potatoes. Ohio. Agr. Exp. Sta. Bul. 218.
[4] Size of Potato Sets: Comparisons of Whole and Cut Seed. U. S. Dept. Agr. Bul. 1248.

The storage conditions necessary to insure vigorous seed at planting time are more easily provided in the North than in the South, because it is easier to maintain the proper temperature in that region. In the North a well-constructed cellar, pit, or cave serves reasonably

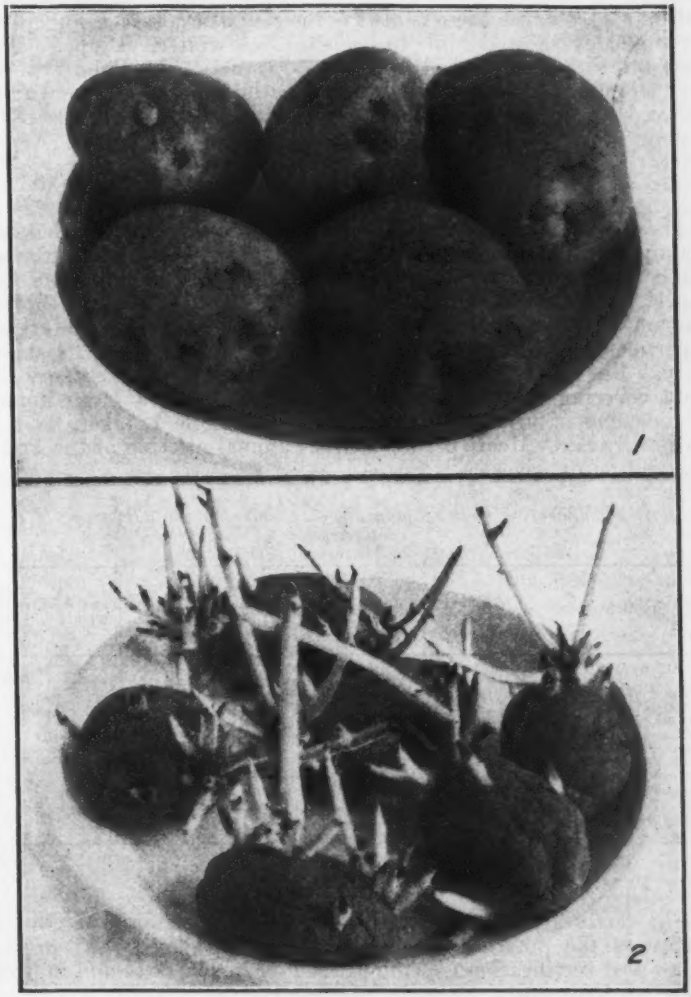

FIGURE 3.—Potatoes to be used for seed, showing different stages of germination: 1, Desirable; 2, undesirable

well. The main requirement is to keep the room temperature low enough to retard germination. The ideal seed tuber is one that has not wasted any of its stored-up energy by excessive loss through sprouting. (Fig. 3.) It should be firm, with the first sprouts just

showing. Such tubers can be depended upon, under suitable conditions, to start quickly when planted and to make a vigorous growth.

In the South, because of the difficulty in preserving proper storage temperatures and thus preventing sprouting, the general practice has been to secure seed stock from the North. This method has difficulties also, because there is always the risk of the seed being chilled, frozen, or overheated while in transit in midwinter. Proper storage facilities such as described in Farmers' Bulletin 847, Potato Storage and Storage Houses, would allow the southern potato grower to have his seed stock shipped to him as soon as it is harvested in the fall or even to grow his own seed if he desires.

CERTIFICATION OF SEED

The rapid increase in acreage and production of certified seed potatoes, and the higher prices which their growers demand, have made it necessary to demonstrate that certified seed potatoes are superior to ordinary seed potatoes. During the time when the production of certified seed was being developed, there was not enough experimental evidence to support the growers' claims of its superiority. But now there is abundant evidence of that superiority. Data covering actual comparative tests made by a large number of independent investigators are shown in Table 1, taken from an address by H. C. Moore before the 1924 annual meeting of the Potato Association of America.

TABLE 1.—*Comparative tests of potato yields, showing the advantage of using certified seed*

Location of tests	Tests or reports	Average increase in yields per acre	Location of tests	Tests or reports	Average increase in yields per acre
	Number	*Bushels*		*Number*	*Bushels*
Canada (8 Provinces)	15	88	Michigan	314	73
Connecticut	144	53	Missouri	46	43
Delaware	21	83	Montana	2	219
Illinois	15	47	Nebraska	64	141
Indiana	9,740	44	New York	68	76
Kansas	11	41	Ohio	168	48
Kentucky	220	42	Oregon	3	150
Louisiana	31	42	Pennsylvania	87	41
Maine	279	83	South Carolina	8	31
Massachusetts		75			

REQUIREMENTS

Seed certification is a system of official inspection whereby the quality of the potato-seed stock may be guaranteed. At present potato-seed certification is being carried on in 22 States and in every Canadian Province.

It is purely voluntary on the part of seed-potato growers in the States and Provinces in which the service is available. In many States, however, the applicant for seed certification must previously have submitted to the official in charge of the certification work a sample of the seed stock he proposes to plant, or he must plant certified seed approved by that official. A number of States also require that an isolated seed plot be maintained.

All seed-potato certification agencies have promulgated rules and regulations designed to insure a high degree of freedom from disease. Practically all these agencies require that two field inspections of the growing plants and a subsequent examination of the tubers at the bin or shipping point be made by their authorized inspectors before they will issue certification tags. This procedure guarantees the purchaser and user that such seed is free from any appreciable amount of tuber-borne diseases, especially those of the virus type. While there are differences in the percentage of disease tolerated in the different seed-producing States, they are not sufficiently great to materially affect the quality of the seed. Certain requirements as to trueness to name, freedom from varietal mixture, vigor of plants, yield, tuber type, percentage of mechanical injuries, etc., are also made in seed certification. The personal factor is generally recognized as of greater importance than rigidity of rules and regulations.

The producer of high-grade seed potatoes is justly entitled to a fair monetary return for the special efforts he has made to produce high-quality seed stock, especially if he has maintained a seed plot year after year and his crop has been officially inspected and passed by an authorized seed-certification inspection officer.

VOLUME OF PRODUCTION

The extent of the seed-potato certification movement and the volume of production are indicated by Table 2, which gives for 1923–1932 the production, in bushels, of certified seed potatoes in the 22 States in which seed certification has been undertaken. The volume of production during the last half of the decade shows an average increase of more than 45 per cent over that of the first five years. The year of greatest production was 1928, in which over 10,250,000 bushels were certified.

TABLE 2.—*Production of certified seed potatoes (bushels) in 22 States, 1923–1932* [1]

State	1923	1924	1925	1926	1927
California			12,050	12,075	17,800
Colorado		22,037	28,560	31,300	77,105
Idaho	92,500		278,148	371,479	866,162
Kentucky	3,200	7,550	14,622	22,920	25,500
Maine	2,140,875	5,052,681	2,226,050	2,294,845	3,278,101
Maryland	7,000		8,205	18,390	32,078
Michigan	272,794	291,086	214,656	337,000	162,397
Minnesota	511,588	777,800	596,605	693,685	621,999
Montana	14,374	31,950	67,800	113,365	180,562
Nebraska	192,880	79,750	121,200	60,200	181,500
New Hampshire	15,183	30,328	12,287	2,695	14,778
New Jersey	23,100	81,850	57,911	92,916	[2] 475
New York	239,031	363,065	210,700	225,371	323,080
North Dakota	72,663	101,836	171,110	181,400	321,305
Ohio	11,025	11,230	4,120	5,600	6,300
Oregon		15,900	27,600	46,000	87,840
Pennsylvania	52,151	65,000	25,965	41,115	29,870
South Dakota			23,600	28,441	49,856
Vermont	127,500	225,000	108,655	160,031	252,582
Washington	28,760		17,550	30,300	121,350
Wisconsin	387,875	357,074	165,025	196,500	243,000
Wyoming	70,000		21,000	138,000	259,500
Total	4,262,499	7,514,137	4,411,419	5,103,628	7,153,140

[1] Data supplied by the Bureau of Agricultural Economics, U. S. Department of Agriculture.
[2] The second crop developed primary leaf-roll symptoms and nearly all fields were rejected.

TABLE 2.—*Production of certified seed potatoes (bushels) in 22 States, 1923–1932*—Continued

State	1928	1929	1930	1931	1932
California	12,000	11,768	4,200	8,750	[3]
Colorado	57,890	71,450	51,945	95,580	122,530
Idaho	349,509	203,717	314,803	224,232	161,480
Kentucky	8,754	21,117	9,050	9,088	11,800
Maine	5,094,128	3,998,902	2,709,554	4,628,780	2,920,669
Maryland	21,581	40,488	16,808	65,948	57,408
Michigan	854,742	741,215	212,125	193,642	370,664
Minnesota	1,162,540	911,099	548,291	662,528	437,266
Montana	236,499	72,380	68,962	62,142	63,965
Nebraska	152,400	462,450	663,000	384,000	392,001
New Hampshire	17,250	9,264	34,960	39,650	12,925
New Jersey	100,355	62,286	49,666	109,177	75,406
New York	470,528	572,100	715,835	819,220	557,950
North Dakota	539,855	412,300	372,000	413,000	824,620
Ohio	6,150	6,400	4,800	6,000	7,000
Oregon	154,237	137,711	74,050	136,635	188,210
Pennsylvania	60,490	69,760	46,016	91,113	103,197
South Dakota	59,309	59,206	27,790	35,350	40,175
Vermont	136,119	136,531	132,850	219,140	177,886
Washington	81,825	76,900	85,085	115,363	93,301
Wisconsin	448,400	293,360	261,391	258,596	172,900
Wyoming	350,000	185,500	299,780	187,338	130,935
Total	10,374,561	8,555,904	6,702,961	8,765,272	6,929,058

[3] Data not available.

Maine has easily been the leader in volume of production.

Figures on the production of certified seed of 10 of the leading commercial varieties in the United States, as given in Table 3, show that the Irish Cobbler, Green Mountain, and Triumph varieties lead in number of bushels certified.

TABLE 3.—*Production of certified seed potatoes (bushels) in the United States, by varieties, 1923–1932* [1]

Variety	1923	1924	1925	1926	1927
Irish Cobbler	942,893	2,402,126	1,402,587	1,969,042	2,262,239
Triumph	490,690	368,764	302,255	418,546	976,826
Spaulding Rose	207,141	1,060,194	453,918	595,647	597,430
Early Ohio	238,708	327,795	181,691	172,263	153,478
Burbank	7,016	5,100	16,100	18,100	38,955
Russet Burbank (*Netted Gem*)	90,917	53,975	446,016	529,157	1,026,592
Green Mountain	1,660,998	2,619,560	1,052,032	798,917	1,571,267
Charles Downing (*Idaho Rural*)	29,200	----------	38,458	13,958	52,398
Rural New Yorker No. 2	263,444	224,898	131,084	541,882	134,196
Russet Rural	363,538	342,490	213,982	345,454	200,675

Variety	1928	1929	1930	1931	1932
Irish Cobbler	3,562,126	2,593,869	1,843,473	2,945,996	2,203,335
Triumph	1,337,496	1,233,769	1,157,980	939,113	1,003,269
Spaulding Rose	791,905	483,539	410,280	577,772	221,994
Early Ohio	224,653	186,967	182,279	280,528	366,454
Burbank	68,288	82,092	30,330	40,533	26,690
Russet Burbank (*Netted Gem*)	550,721	313,961	439,593	384,179	343,139
Green Mountain	2,479,174	2,230,965	1,679,078	2,722,315	1,635,714
Charles Downing (*Idaho Rural*)	15,085	14,276	15,883	6,425	6,901
Rural New Yorker No. 2	261,571	268,074	243,042	237,739	223,940
Russet Rural	925,826	894,933	414,797	451,169	594,929

[1] Data from the Hay, Feed, and Seed Division, Bureau of Agricultural Economics, U. S. Department of Agriculture.

RESTRICTED USE

It is obvious from the foregoing information on the value of certified seed potatoes and the extent of their production that growers of potatoes for either commercial or home use are not yet fully convinced of the advantage of planting certified seed.

Even after more than 15 years of seed certification less than one-fourth of the total potato acreage of the United States is planted with certified seed. The reason for this seeming neglect by growers may well be considered. The data in Table 1 clearly show a distinct gain in yield, ranging from 31 to 219 bushels an acre, from the use of certified seed. Obviously, failure to use certified seed can not be ascribed to lack of performance of the seed in increasing yield.

Two factors are probably involved in this failure: (1) Price difference between certified and uncertified seed; and (2) indifference of the grower to quality of seed. In regard to the first factor, purchasers of certified seed may consider that many growers demand a larger price premium than is warranted. However, the price premium is partly justified by the exacting demands of the purchaser in regard to freedom of the tubers from mechanical injuries, from surface diseases such as common scab and rhizoctonia, and from undersized and oversized potatoes. To meet purchasers' requirements the grower must often discard a considerable percentage of his stock, thereby reducing his profits. In order to reduce such grading losses the grower must select land as free from scab and rhizoctonia infestation as possible; he must control the size of tubers by closer planting or the use of larger seed pieces, and he must lessen mechanical injury by more careful harvesting and handling.

By observing such practices the grower can lessen materially the percentage of the crop that fails to come within grade requirements and thereby remove the necessity for demanding a seemingly high premium for his seed stock.

The use of bogus seed-certification tags has also seriously curtailed the use of certified seed, because of the poor performance of stock so tagged and the failure of the purchaser or user to recognize that it was not bona fide certified seed. The would-be purchaser of certified seed should learn to distinguish between genuine and bogus seed-certification tags.

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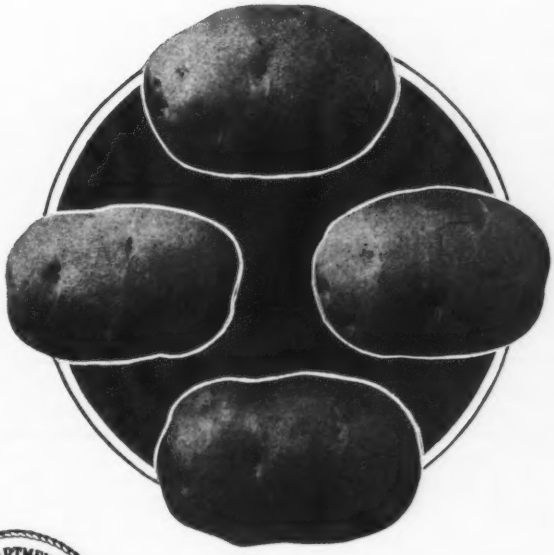
U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1332

Rev. Nov. 1936

SEED POTATOES AND HOW TO PRODUCE THEM



THE IMPORTANCE of planting good seed potatoes is not appreciated as fully as it should be. Good seed is one of the determining factors in profitably producing maximum crops of potatoes.

The quality of the seed can be improved by removing all diseased, weak, or off-type plants as soon as they are observable.

Good seed can be produced only by giving the growing plants good cultural attention.

Only seed from productive plants should be used.

Seed should be free from varietal mixture and true to type.

Good storage conditions are essential in insuring sound, firm seed at planting time.

All seed stock should be disinfected before it is planted.

This bulletin is a revision of and supersedes Farmers' Bulletin 533, Good Seed Potatoes and How to Produce Them.

Washington, D. C.

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SEED POTATOES AND HOW TO PRODUCE THEM

By WILLIAM STUART, formerly *senior horticulturist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry*

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IMPORTANCE OF GOOD SEED

THE USE OF GOOD SEED is especially important in lowering the unit cost of potato production. Lowering unit cost does not necessarily mean lowering the quality or the price of a bushel of potatoes, but, rather, furnishing a better product without increasing the cost of its production. The progressive potato grower's aim should be to produce as many profitable bushels per acre as possible.

Two factors determine the quality of seed potatoes: (1) The physical or outward appearance of the tubers and (2) the heritable or transmissible characters of the stock. The first involves the purity and maturity of the stock, uniformity in size and shape of the tubers, brightness of skin, firmness of flesh with first sprouts just showing, and freedom from scab, Rhizoctonia, late blight, or other tuber-decay diseases. The second factor deals with nonobservable characters and is by far the most important, as it involves the presence or absence of the virus diseases causing mosaic, leaf roll, spindle tuber, streak, and yellow dwarf. Freedom from the virus diseases is important and can only be assured by inspection of the growing plants from which the seed was obtained or by the purchase of reliably certified stock.

DEVELOPMENT OF HIGH-GRADE SEED

SELECTION METHODS

The chief improvement to be made in seed-potato stocks by selection methods is the elimination of diseased and weak plants and of varietal mixtures. Experimental evidence seems to indicate that the possibilities of improving seed stock by selective practices alone are not so great as has been claimed, and that the chances of

finding superior-yielding, true-to-type strains within a variety are more limited than was once believed.

Five methods of improvement may be used in obtaining a commercially desirable strain of potatoes: (1) The tuber-indexing method, (2) the tuber-unit method, (3) hill selection, (4) mass selection, and (5) field roguing.

TUBER-INDEXING METHOD

The tuber-indexing method of seed-potato improvement is the most recently devised and most effective method of eliminating diseased, weak, and low-yielding potato tubers from seed stock intended for planting in the seed plot. The work is usually done during the winter. The first step is to select as many tubers, each weighing from 7 to 9 ounces or thereabouts, as greenhouse, hotbed, or outdoor space will accommodate. The next step is to number each tuber for identification and then remove a seed piece or set from each, preferably from the seed end, although any strong eye will serve. This set is then put in a suitable-sized pot (the 3½ or 4-inch size is satisfactory), or it may be planted in a greenhouse bench or hotbed. In either case the set must be labeled with the number of the tuber from which it was taken. The plants produced from these seed pieces are carefully observed for virus diseases, such as the various types of mosaic, leaf roll, spindle tuber, and the yellow dwarf. All plants showing any of these diseases or any sign of weakness are noted, and the seed tubers from which the sets were taken are discarded. In this way it is possible to get rid of most if not all of the diseased tubers before planting them.

The best method of handling the mother tubers from which the index sets have been removed is to hold them for 10 days to 2 weeks in a temperature of 60° to 70° F., after which they may be held at 40° to 45° until planting. The higher temperature with relatively high humidity favors thorough healing of the cut surface.

The extent to which this work can be done in the North, except in regions where a late or fall crop of potatoes can be grown, is necessarily limited to the greenhouse or hotbed space available. Where a fall or second crop is grown, as in southern New Jersey, the Eastern Shore of Maryland and Virginia, and practically all of the Southern States, it is possible to practice the tuber-indexing method with the spring crop by planting the set from the numbered tuber in the open field and properly labeling it. Observations can be made during the growing season in ample time for a second-crop planting of indexed tubers that are apparently free from disease as well as from any inherent weakness. By doing such work in the far South it would be possible to grow the indexed set to full maturity before the normal planting period in the North. In fact, certain State seed-certification agencies are now resorting to this practice in order to get a "reading" on the behavior of their certified strains of seed potatoes. At the usual planting time the tubers found to be free from disease are planted in a seed plot by themselves, the pieces from each tuber being planted separately. It is then easy to identify, in the growing plants, any disease from an infected tuber that may have escaped the observer of the tuber-index set. From this point in the process the practices are the same as those under the tuber-unit method.

TUBER-UNIT METHOD

The tuber-unit method consists in selecting from the seed bin before planting time a considerable number of the most perfectly shaped tubers ranging from 6 to 8 ounces in weight. In planting, these tubers are quartered, as dropped, into parts as nearly equal as possible, by splitting the bud-eye cluster twice from seed to stem end of the tuber. In other words, the tuber is cut through its longitudinal axis. The four pieces of each tuber are dropped consecutively in the row, 10 to 12 inches apart. All tubers showing discoloration of the flesh or other evidence of disease should be rejected. By allowing an additional spacing between sets of fours, the four plants from each tuber are definitely isolated and the grower can readily observe any variation in vigor and uniformity among the various units planted. This method also enables him to detect any mixtures in the variety. All mixtures should be removed at once. The units that appear most uniform in size, vigor, and type when the plants are still in vigorous growth are marked, and the first step in selection has been accomplished. At digging time the product of each unit is separately harvested and a further selection made from the marked units of all tubers which most nearly approach the size, shape, and smoothness desired. The selected tubers of each unit should be separately placed in small sacks, preferably cotton or burlap, numbered with both field and unit numbers, and stored to await further examination. The final examination should produce data on the number and weight of merchantable and unmerchantable tubers and their general conformity in size, shape, and smoothness to the type desired. From each of the units retained 10 of the best tubers should be selected for the next season's planting.

It is desirable to maintain the study of each selection on the tuber-unit basis the following season, because it permits a more accurate comparison of the behavior of each. The 10 selected tubers from each original unit will give 40 plants for study the second year. All selections which do not produce a reasonably uniform lot of plants should be rejected. At harvest time the progeny of each selection should be kept by itself and the same data recorded as those taken on the crop grown from the original tuber unit. Only the products from such 40-hill rows as meet the most rigid requirements should be retained. The further work will consist in multiplying the selected strains for field planting and eliminating the weak plants.

HILL SELECTION

The hill-selection method consists in marking the most promising plants during the growing season and at harvesting time saving only the progeny of the best. (Figs. 1 and 2.) The progeny of each hill should be kept separate and the same data taken as outlined for the tuber unit. Plant on the tuber-unit or progeny-row basis the following season. For the sake of uniformity a definite number of tubers (five or more) from each hill selection should be planted. Subsequent procedure should follow the practices given for the tuber-unit method.

FIGURE 1.—Progeny of (*A*) a mosaic-infected potato plant of the Triumph variety and (*B*) a healthy plant. Bin selection of such seed would result in taking at least two tubers from the mosaic plant. If small tubers were used all would come from diseased plants. In hill-selection work only the progeny of plant *B* would be saved.

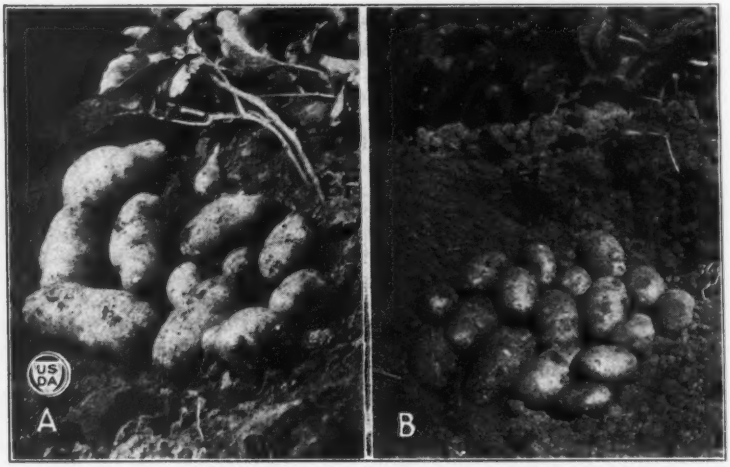

FIGURE 2.—Progeny from (*A*) abnormal and (*B*) normal plants of the Russet Burbank potato. Plant *A* is known in the West as a degenerate or run-out plant, and the disease with which it is affected is probably identical with that termed "spindle tuber." It is a communicable disease and may become serious. In hill-selection work only the progeny of plants such as *B* would be saved.

MASS SELECTION

Mass selection differs from hill selection in only one respect, that is, the tubers from the individually selected plants are not kept separate. Generally growers who practice mass selection do not go to the trouble of marking promising individual plants during the growing season, but simply go through the field before harvesting the whole crop and dig by hand as many plants that show the desired vigor and stem characters thought to be correlated with productiveness, trueness to type, and uniformity in size of tubers of the particular variety grown, as may be desired to secure the necessary quantity of seed.

FIELD ROGUING

By "roguing" vegetable-seed growers mean improving the seed stock by the process of removing all "rogues"—diseased, weak, off-type, or varietally mixed plants—from the field or seed plot during the growing season, when the process is relatively easy. Roguing does not necessarily require an intimate knowledge of the various potato diseases, but it does call for the ability to tell whether a plant is normal or abnormal in appearance. Varietal mixtures are more easily detected when the plants are in bloom. Weak plants are usually easy to detect in the early stages of their growth, as are also certain types of disease such as mosaic and blackleg, although both weakness and disease may appear later. Infection with Rhizoctonia and Fusarium is usually not apparent until the latter part of the growing season. The area should be gone over at least three times during the growing season. In field roguing a sufficient area should be covered the first year to provide enough seed to plant the full acreage that is to be grown the ensuing season. When the crop of the seed plot is harvested, further roguing should be done by discarding the progeny of all low-producing plants. (Fig. 1, *A*.)

RELATIVE MERITS OF THE DIFFERENT METHODS

Careful consideration of all the experimental evidence at hand seems to justify the conclusion that in the hands of an especially trained individual the tuber-indexing method is without doubt the most effective process for eliminating diseased tubers and for creating foundation stock from which to produce high-class seed stock. The tuber-unit method is the next most promising. When it is practiced in connection with hill selection it should prove much more effective than when used in connection with bin-selected stock. The first three methods can be recommended only to those growers and specialists who are capable of giving the thought and time necessary to produce results. Mass selection and field roguing present greater possibilities in the hands of the average grower who does not have time or inclination to give the care required for best results.

The only requirements for the successful practice of the tuber-unit, hill-selection, and mass-selection methods are a reasonable degree of painstaking effort on the part of the grower, some 12-inch garden labels, a small pair of balances, a sufficient number of small sacks, a safe place in which to store the selected tubers until they are required for the next season's planting, and a breeding plot in which each season's selections can be developed into planting stock. The selection

or seed plot should be located as far from the commercial potato field as possible, in order to secure the greatest degree of isolation feasible.

ISOLATION

It is now recommended that in producing seed potatoes under isolation, each variety be grown separately, because it has been found that stocks of certain varieties supposed to be free from mosaic have served as carriers of disease to more susceptible varieties. The ultimate success in using the isolated seed plot in eliminating tuber-borne diseases rests largely on the ability of the grower to recognize diseased plants and his promptness in removing them from the seed plot and destroying them. Heretofore, the factor of isolation has not received due consideration, largely because the seriousness of such diseases as mosaic, leaf roll, curly dwarf, streak, and spindle tuber had not been recognized. The fact that all of these diseases are readily transmitted from diseased to healthy plants through the instrumentality of plant lice or aphids and the further fact that as yet there is no reliable information on the distance over which insects may transport these diseases, suggest an isolation of the seed plot as complete as possible.

Frequent and thorough inspections of the seed plot are necessary to insure the largest possible elimination of diseased plants and to reduce the transmission of disease from diseased to healthy plants.

SEED TREATMENT

It is impossible to produce high-grade seed potatoes if the seed planted is infected with disease organisms capable of infecting the crop. Disinfection of the seed potatoes is therefore necessary if the best results are to follow. The two diseases for which seed potatoes are ordinarily treated are common scab and black scurf, or Rhizoctonia. The two disinfecting agents recommended for such treatment are formalin and corrosive sublimate (mercuric chloride, or bichloride of mercury). Formalin is a trade name for a 40-percent solution of formaldehyde gas. Corrosive sublimate is a white crystalline poisonous compound which goes into solution very slowly in cold water but is readily dissolved in boiling water. The hot-formaldehyde treatment of seed has been found much more effective against black scurf (rhizoctonia) than the cold-solution treatment, and requires a much shorter period of immersion. The formulas recommended for these two disease disinfectants are:

1. Formalin:
   a. Cold treatment:
      Formalin, 1 pint.
      Water, 30 gallons.
   b. Hot treatment:
      Formalin, 2 pints.
      Water, 30 gallons, heated to 125° F.
2. Corrosive sublimate, 4 ounces.
   Water, 30 gallons.

The period of treatment for formula 1, *a*, and for formula 2 is from 1½ to 2 hours when the seed is dormant and one-half to 1½ hours if the tubers are germinated. With formula 1, *b*, on account of the double strength of the solution and the higher temperature of the liquid, the period of treatment is cut to 4 or 5 minutes. In using the hot formaldehyde solution it is necessary to have a reliable

thermometer and a well-controlled method of maintaining a uniform temperature throughout the treatment.

The treated tubers should on no account be allowed to come in contact with such receptacles as sacks and barrels in which diseased seed has been handled, as these articles are almost certain to be sources of reinfection.

SOIL PREPARATION AND CULTURAL PRACTICES

Strong, vigorous plants cannot be produced on land that has been poorly prepared or that is deficient in available plant food. Seed potatoes should be grown on land that has been deeply plowed and thoroughly prepared to receive the seed. It should be well supplied with organic matter and available plant food. A clover or alfalfa sod furnishes the organic matter and considerable plant food. Barnyard manures or commercial fertilizers, or both, will supply the additional plant food necessary.

The vigor of the seed stock produced depends largely on the care given to the growing crop. Uniformity in the size of the tubers is largely governed by the rate of planting. Closer planting should be practiced in growing seed than in growing table stock. Some growers in Aroostook County, Maine, space their rows 32 to 36 inches apart and the plants in the row 8 to 12 inches. The crop should be cultivated as frequently as may be necessary to provide the most suitable growing conditions.

The plants should be sprayed to prevent injury by insect or fungus pests. Leaf-eating insects can be effectively controlled by thorough spraying with arsenical poisons; sucking insects, with contact solutions, such as kerosene emulsion and nicotine; and fungus diseases, such as the early and late blights, with bordeaux mixture. In every operation it should be remembered that whatever contributes to the health of the plant increases the vigor of the seed stock produced.

IMPORTANCE OF TUBER SHAPE AND SIZE

Reasonable trueness of the tubers to varietal type is generally demanded by the purchaser of certified seed. The Irish Cobbler grower in the South demands roundish tubers and is suspicious of the purity of seed stock that contains flattened and somewhat elongated tubers; he generally protests against accepting them as strictly first-class seed stock, and is inclined to regard the off-type tubers as Green Mountain.

However, some scientific workers and practical growers are now disposed to regard tuber shape as being less important than was previously supposed. They have come to regard tubers that have departed from the type because of unfavorable environmental conditions as being satisfactory for seed purposes, and as no more likely to produce off-type progeny than are normal-shaped tubers. This, however, does not apply to tubers that are off-type as a result of disease; such tubers should not be planted. The spindle tuber, now recognized as a communicable disease, is very similar to leaf roll and the mosaic disease in its method of transmission. Figure 2, *A*, pictures a fairly good example of spindle tubers. It is important, therefore, in purchasing somewhat off-type seed potatoes to know

that the change in shape is really due to unfavorable environmental factors and not to disease.

In seasons of short production and consequent high prices for table stock the question of whether it is advisable to use the small, unsalable tubers for seed is frequently raised. It is always unsafe to use small tubers for seed unless it is absolutely certain that they have been produced by healthy, vigorous, and productive plants. It is never advisable to use small tubers from the general production from unselected stock. Some experimental study of this subject by Ballou and Gourley [1] demonstrated that the planting of large tubers gave—

(1) A very high, sometimes almost total, percentage of the high-producing strains.
(2) A high percentage of the average or moderate-yielding strains.
(3) A very low percentage of the inferior or low-producing strains.

The planting of small tubers gave—

(1) A very insignificant percentage of the high-producing strains.
(2) A low percentage of the moderate-yielding strains.
(3) A very high, almost total, percentage of the low-yielding strains.

WHOLE SEED COMPARED WITH CUT SEED

Experimental evidence does not indicate that whole tubers are better than cut tubers as seed, at least in the United States. The data, while conflicting, show that in general and within reasonable limits the larger the seeds planted, the larger the crop. If whole seed is to be planted, small tubers and those from unselected stock should not be used.

The tubers should be germinated before being planted, to insure a minimum number of sprouts. Planting dormant whole tubers causes too many sprouts to develop.

HARVESTING AND STORAGE

The importance of preventing mechanical injury of the tubers during harvesting and storing is not fully realized. If the land contains small stones, the tubers are almost certain to be more severely injured in harvesting than if they were grown in a sandy loam soil. Hand digging is not always feasible, but where small stones abound in the soil it is desirable to harvest the home seed plot by hand.

Much injury will be avoided if, when harvested, the seed stock designed for planting the field plot of the ensuing year is placed directly in crates in which it can remain throughout the storage period.

The storage conditions necessary to insure vigorous seed at planting time are more easily provided in the North than in the South, because it is easier to maintain the proper temperature in that region. In the North a well-constructed cellar, pit, or cave serves reasonably well. The main requirement is to keep the room temperature low enough to retard germination. The ideal seed tuber is one that has not wasted any of its stored-up energy by excessive loss through

[1] The Status of the Potato-Growing Industry in Ohio. II. Seasonal Notes on Potatoes. Ohio Agr. Exp. Sta. Bul. 218.

sprouting. (Fig. 3.) It should be firm, with the first sprouts just showing. Such tubers can be depended upon, under suitable conditions, to start quickly when planted and to make a vigorous growth.

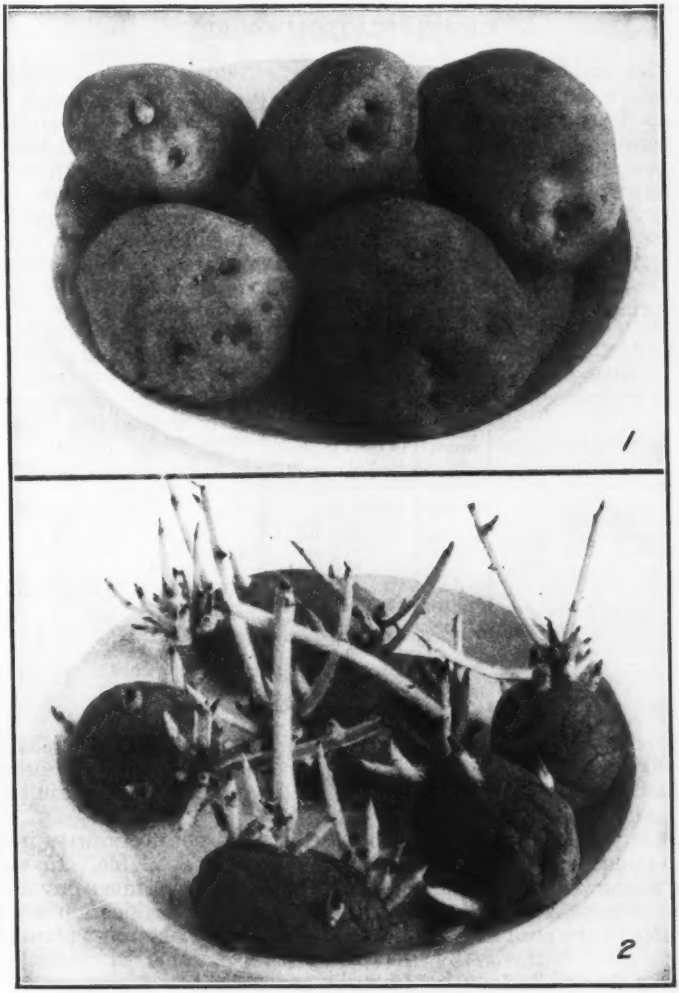

FIGURE 3.—Potatoes to be used for seed, showing different stages of germination: 1, Desirable; 2, undesirable.

In the South, because of the difficulty in preserving proper storage temperatures and thus preventing sprouting, the general practice has been to secure seed stock from the North. This method has difficulties also, because there is always the risk of the seed being chilled, frozen, or overheated while in transit in midwinter. Proper storage

facilities such as described in Farmers' Bulletin 847, Potato Storage and Storage Houses, would allow the southern potato grower to have his seed stock shipped to him as soon as it is harvested in the fall or even to grow his own seed if he desires.

CERTIFICATION OF SEED

The rapid increase in acreage and production of certified seed potatoes, and the higher prices which their growers demand, have made it necessary to demonstrate that certified seed potatoes are superior to ordinary seed potatoes. During the time when the production of certified seed was being developed, there was not enough experimental evidence to support the growers' claims of its superiority. But now there is abundant evidence of that superiority. Data covering actual comparative tests made by a large number of independent investigators are shown in table 1, taken from an address by H. C. Moore before the 1924 annual meeting of the Potato Association of America.

TABLE 1.—*Comparative tests of potato yields, showing the advantage of using certified seed*

Location of tests	Tests or reports	Average increase in yields per acre	Location of tests	Tests or reports	Average increase in yields per acre
	Number	*Bushels*		*Number*	*Bushels*
Canada (8 Provinces)	15	88	Michigan	314	73
Connecticut	144	53	Missouri	46	43
Delaware	21	83	Montana	2	219
Illinois	15	47	Nebraska	64	141
Indiana	9,740	44	New York	68	76
Kansas	11	41	Ohio	168	48
Kentucky	220	42	Oregon	3	150
Louisiana	31	42	Pennsylvania	87	41
Maine	279	83	South Carolina	8	31
Massachusetts		75			

REQUIREMENTS

Seed certification is a system of official inspection whereby the quality of the potato-seed stock may be guaranteed. At present potato-seed certification is being carried on in 26 States and in every Canadian Province.

It is purely voluntary on the part of seed-potato growers in the States and Provinces in which the service is available. In many States, however, the applicant for seed certification must previously have submitted to the official in charge of the certification work a sample of the seed stock he proposes to plant, or he must plant certified seed approved by that official. A number of States also require that an isolated seed plot be maintained.

All seed-potato certification agencies have promulgated rules and regulations designed to insure a high degree of freedom from disease. Practically all these agencies require that two field inspections of the growing plants and a subsequent examination of the tubers at the bin or shipping point be made by their authorized inspectors before they will issue certification tags. This procedure guarantees the purchaser and user that such seed is free from any

appreciable amount of tuber-borne diseases, especially those of the virus type. While there are differences in the percentage of disease tolerated in the different seed-producing States, they are not sufficiently great to materially affect the quality of the seed. Certain requirements as to trueness to name, freedom from varietal mixture, vigor of plants, yield, tuber type, percentage of mechanical injuries, etc., are also made in seed certification. The personal factor is generally recognized as of greater importance than rigidity of rules and regulations.

The producer of high-grade seed potatoes is justly entitled to a fair monetary return for the special efforts he has made to produce high-quality seed stock, especially if he has maintained a seed plot year after year and his crop has been officially inspected and passed by an authorized seed-certification inspection officer.

VOLUME OF PRODUCTION

The extent of the seed-potato certification movement and the volume of production are indicated by table 2, which gives for 1926–35 the production, in bushels, of certified seed potatoes in the 26 States in which seed certification has been undertaken. The volume of production has fluctuated from year to year. It reached a maximum of 12,100,060 bushels in 1935.

TABLE 2.—*Production of certified seed potatoes (bushels) in 26 States, 1926–35* [1]

State	1926	1927	1928	1929	1930
California	12,075	17,800	12,000	11,768	4,200
Colorado	31,300	77,105	57,890	71,450	51,945
Idaho	371,479	866,162	349,509	203,717	314,803
Kentucky	22,920	25,500	8,754	21,117	9,050
Maine	2,294,845	3,278,101	5,094,128	3,998,902	2,709,554
Maryland	18,390	32,078	21,581	40,488	16,808
Michigan	337,000	162,397	854,742	741,215	212,125
Minnesota	693,685	621,999	1,162,540	911,099	548,291
Montana	113,365	180,562	236,499	72,380	68,962
Nebraska	60,200	181,500	152,400	462,450	663,000
New Hampshire	2,695	14,778	17,250	9,264	34,960
New Jersey	92,916	[2] 475	100,355	62,286	49,666
New York	225,371	323,080	470,528	572,100	715,835
North Dakota	181,400	321,305	539,855	412,300	372,000
Ohio	5,600	6,300	6,150	6,400	4,800
Oregon	46,000	87,840	154,237	137,711	74,050
Pennsylvania	41,115	29,870	60,490	69,760	46,016
South Dakota	28,441	49,856	59,309	59,206	27,790
Vermont	160,031	252,582	136,119	136,531	132,850
Washington	30,300	121,350	81,825	76,900	85,085
Wisconsin	196,500	243,000	448,400	293,360	261,391
Wyoming	138,000	259,500	350,000	185,500	299,780
Total	5,103,628	7,153,140	10,374,561	8,555,904	6,702,961

[1] Data from the Hay, Feed, and Seed Division, Bureau of Agricultural Economics, U. S. Department of Agriculture.

[2] The second crop developed primary leaf-roll symptoms, and nearly all fields were rejected

TABLE 2.—*Production of certified seed potatoes (bushels) in 26 States, 1926–35*—Continued

State	1931	1932	1933	1934	1935
California	8,102	6,770	12,467	20,450	71,083
Colorado	95,580	122,530	505,965	425,044	352,458
Idaho	226,066	151,497	212,394	136,404	107,273
Kentucky	9,088	11,800	12,210	9,110	7,135
Louisiana				37,000	11,940
Maine	3,944,036	2,920,600	3,852,796	6,003,342	5,872,000
Maryland	65,948	57,408	72,572	94,713	45,710
Michigan	193,642	370,664	271,780	348,880	217,206
Minnesota	662,528	437,266	602,105	658,818	1,345,313
Montana	62,142	63,965	60,845	67,450	120,072
Nebraska	384,000	392,001	552,263	195,623	814,705
New Hampshire	39,650	12,925	29,666	35,325	27,846
New Jersey	114,168	83,899	123,908	106,540	44,095
New Mexico					7,000
New York	819,220	550,042	520,000	544,000	415,300
North Carolina				41,500	20,500
North Dakota	413,000	824,620	918,150	628,310	1,430,300
Ohio	6,000	7,000	8,000	400	5,000
Oregon	136,635	188,210	185,300	187,400	130,170
Pennsylvania	91,113	103,247	137,165	241,789	147,154
South Dakota	37,938	40,175	3,945	7,010	19,827
Utah				36,550	42,150
Vermont	219,140	179,042	183,100	209,800	154,915
Washington	115,363	93,301	101,966	101,435	99,508
Wisconsin	258,596	172,900	149,450	179,918	201,700
Wyoming	187,338	130,935	303,950	143,050	389,700
Total	8,089,293	6,920,797	8,819,997	10,459,865	12,100,060

Maine has easily been the leader in volume of production.

Figures on the production of certified seed of 10 of the leading commercial varieties in the United States, as given in table 3, show that the Irish Cobbler, Green Mountain, and Triumph varieties lead in number of bushels certified.

TABLE 3.—*Production of certified seed potatoes (bushels) in the United States, by varieties, 1926–35* [1]

Variety	1926	1927	1928	1929	1930
Irish Cobbler	1,969,042	2,262,239	3,562,126	2,593,869	1,843,473
Triumph	418,546	976,826	1,337,496	1,233,769	1,157,980
Spaulding Rose	595,647	597,430	791,995	483,539	410,280
Early Ohio	172,263	153,478	224,653	186,967	182,279
Burbank	18,100	38,955	68,288	82,092	30,330
Russet Burbank (Netted Gem)	529,157	1,026,592	550,721	313,961	439,593
Green Mountain	798,917	1,571,267	2,479,174	2,230,965	1,679,078
Charles Downing (Idaho Rural)	13,958	52,398	15,085	14,276	15,883
Rural New Yorker No. 2	541,882	134,196	261,571	268,074	243,042
Russet Rural	345,454	200,675	925,826	894,933	414,797

Variety	1931	1932	1933	1934	1935
Irish Cobbler	2,945,996	2,205,961	2,822,283	3,827,237	4,782,641
Triumph	939,113	1,003,269	1,443,172	881,120	2,246,110
Spaulding Rose	577,772	221,674	367,903	489,110	336,700
Early Ohio	280,528	366,605	450,505	235,776	435,511
Burbank	40,533	26,690	53,800	39,100	26,200
Russet Burbank (Netted Gem)	384,179	334,066	420,735	401,398	326,294
Green Mountain	2,722,315	1,640,152	1,842,097	3,062,020	2,583,255
Charles Downing (Idaho Rural)	6,425	6,115	6,392	1,925	4,250
Rural New Yorker No. 2	237,739	225,918	245,047	281,013	143,793
Russet Rural	451,169	589,659	475,640	556,449	346,239
Other varieties		300,688	692,423	744,713	862,067

[1] Data from the Hay, Feed, and Seed Division, Bureau of Agricultural Economics, U. S. Department of Agriculture.

USE

It is obvious from the foregoing information on the value of certified seed potatoes and the extent of their production that not all growers of potatoes for either commercial or home use are yet fully convinced of the advantage of planting certified seed.

Even after more than 20 years of seed certification less than one-fourth of the total potato acreage of the United States is planted with certified seed. The reason for this seeming neglect by growers may well be considered. The data in table 1 clearly show a distinct gain in yield, ranging from 31 to 219 bushels an acre, from the use of certified seed. Obviously, failure to use certified seed cannot be ascribed to lack of performance of the seed in increasing yield.

Two factors are probably involved in this failure: (1) Price difference between certified and uncertified seed; and (2) indifference of the grower to quality of seed. In regard to the first factor, purchasers of certified seed may consider that many growers demand a larger price premium than is warranted. However, the price premium is partly justified by the exacting demands of the purchaser in regard to freedom of the tubers from mechanical injuries, from surface diseases such as common scab and rhizoctonia, and from undersized and oversized potatoes. To meet purchasers' requirements the grower must often discard a considerable percentage of his stock, thereby reducing his profits. In order to reduce such grading losses the grower must select land as free from scab and rhizoctonia infestation as possible; he must control the size of tubers by closer planting or the use of larger seed pieces, and he must lessen mechanical injury by more careful harvesting and handling.

By observing such practices the grower can lessen materially the percentage of the crop that fails to come within grade requirements and thereby remove the necessity for demanding a seemingly high premium for his seed stock.

The use of bogus seed-certification tags has also seriously curtailed the use of certified seed, because of the poor performance of stock so tagged and the failure of the purchaser or user to recognize that it was not bona fide certified seed. The would-be purchaser of certified seed should learn to distinguish between genuine and bogus seed-certification tags.

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